DTU Library

Environmental Radioactivity in the North Atlantic Region including the Faroe Islands and Greenland 1987

Aarkrog, A.; Buch, E.; Chen, Q.J.; Christensen, G.C.; Dahlgaard, H.; Hansen, H.; Holm, E.; Nielsen, Sven Poul

Publication date:
1989

Document Version
Publisher's PDF, also known as Version of record

DK9000033

RISØ

Risø-R-564

Environmental Radioactivity in the North Atlantic Region Including the Faroe Islands and Greenland. 1987

A. Aarkrog, E. Buch, Q.J. Chen, G.C. Christensen, H. Dahlgaard, H. Hansen, E. Holm, and S.P. Nielsen

Risø National Laboratory, DK-4000 Roskilde, Denmark
July 1989

Risø-R-564

Environmental Radioactivity in the North Atlantic Region Including the Faroe Islands and Greenland. 1987

A. Aarkrog, E. Buch°, Q.J. Chen, G.C. Christensen*, H. Dahlgaard, H. Hansen, E. Holm, and S.P. Nielsen**

° The Greenland Fisheries and Environmental Research Institute, Denmark
* Institute for Energy Technology, Kjeller, Norway
** International Laboratory of Marine Radioactivity, Monaco

Risø National Laboratory, DK-4000 Roskilde, Denmark
July 1989

Abstract. Measurements of fallout radioactivity in the North Atlantic region including Faroe Islands and Greenland are reported. Strontium-90, cesium-137 and cesium-134 were determined in samples of precipitation, sea water, vegetation, various foodstuffs (including milk in the Faroes), and drinking water. Estimates are given of the mean contents of ^{90}Sr and ^{137}Cs in human diet in the Faroes and Greenland in 1987. ^{99}Tc data on marine samples are reported. Data on plutonium and americium in sediments and biota collected at Thule in 1984 are presented.

ISBN 87-550-1533-6
ISSN 0106-2840
ISSN 0900-8098

Grafisk Service, Risø, 1989

CONTENTS

Abbreviations and Units

J: joule: the unit of energy; 1 J = 1 Nm (= 0.239 cal)
Gy: gray: th unit of absorbed dose = 1 J kg^{-1} (= 100 rad)
Sv: sievert: the unit of dose equivalent = 1 J kg^{-1} (= 100 rem)
Bq: becquerel: the unit of radioactivity = 1 s^{-1} (= 27 pCi)
ALI: annual limit of intake (according to ICRP)

cal: calorie = 4.186 J
rad: 0.01 Gy
rem: 0.01 Sv
Ci: curie: $3.7 \cdot 10^{10}$ Bq (= $2.22 \cdot 10^{12}$ dpm)

E: exa: 10^{18}
P: peta: 10^{15}
T: tera: 10^{12}
G: giga: 10^{9}
M: mega: 10^{6}
k: kilo: 10^{3}
m: milli: 10^{-3}
μ: micro: 10^{-6}
n: nano: 10^{-9}
p: pico: 10^{-12}
f: femto: 10^{-15}
a: atto: 10^{-18}

pro capite: per individual
TNT: trinitrotoluol; 1 Mt TNT: nuclear explosives energy equivalent to 10^{9} kg TNT.

a^{-1}: per annum, (yr^{-1})
OR: observed ratio
CF: concentration factor
μR: micro-roentgen, 10^{-6} roentgen
S.U.: pCi ^{90}Sr (g Ca)$^{-1}$
O.R.: observed ratio
M.U.: pCi ^{137}Cs (g K)$^{-1}$
V: vertebrae
m: male
f: female
nSr: natural (stable) Sr

eqv. mg KCl: equivalents mg KCl: activity as from 1 mg KCl (~0.88 dpm). 1 g K ~ 28 Bq. ~ 756 pCi.

S.D.: standard deviation: $\sqrt{\frac{\Sigma(\bar{x}-x_i)^2}{(n-1)}}$

S.E.: standard error $\sqrt{\frac{\Sigma(\bar{x}-x_i)^2}{n(n-1)}}$

U.C.L.: upper control level
L.C.L.: lower control level

Δ : one standard deviation due to counting
S.S.D.: sum of squares of deviation: $\Sigma(x-x_i)^2$
f: degrees of freedom
s^2: variance
v^2: ratio of the variance in question to the residual variance
P: probability fractile of the distribution in question
η : coefficient of variation, relative standard deviation
anova: analysis of variance
Counting errors: given as relative standard deviation:
no indication: < 20%
A: 20-33%
B: >33%, such results are not considered significantly different from zero activity
B.D.L.: below detection limit
d.w.: dry weight

In the significance test, the following symbols were used:
* : probably significant (P > 95%)
** : significant (P > 99%)
***: highly significant (P > 99.9%)

1. General Introduction

Since 1962 we have published separate annual reports on Environmental Radioactivity in the Faroes[1] and Greenland[2]. The reports for 1983 and after are contained in the new series: »Environmental Radioactivity in the North Atlantic Region. The Faroe Islands and Greenland included«[4] of which the present report is the fifth.

Chapter 2 in this report corresponds to the earlier report for the Faroes and Chapter 3 to the Greenland report.

In Chapter 4 we report on marine environmental radioactivity studies from other parts of the North Atlantic region and, furthermore, include sea water data from the Faroe Islands and Greenland. Chapter 4 also includes results from samplings carried out in earlier years.

Due to the burden of work after the Chernobyl accident in 1986, this report appears with several months delay.

The "normal" sampling programmes in the Faroes and Greenland were expanded after the Chernobyl accident in order to evaluate the contamination from Chernobyl in these areas.

2. Environmental Radioactivity in the Faroe Islands in 1987

2.1. Introduction

2.1.1.

The fallout programme for the Faroes, which was initiated in 1962[1] in close co-operation with the National Health Service and the chief physician of the Faroes, was continued with some adjustments due to the Chernobyl accident in 1986. A special sampling was carried out by Risø in July in order to compare the environmental behaviour of Chernobyl debris with that from old global fallout. Samples of human bone were obtained in 1987 from Dronning Alexandrine's Hospital in Thorshavn.

2.1.2.

The present report will not repeat information concerning sample collection and analysis already given in Risø Reports Nos. 64, 86, 108, 131, 155, 181, 202, 221, 246, 266, 292, 306, 324, 346, 361, 387, 404, 422, 448, 470, 488, 510, 528, 541 and 550[1,4].

2.1.3.

The mean diet of the Faroese used in this report is still based on the 1962 estimate given by the late Professor E. Hoff-Jørgensen.

2.1.4.

The present investigation was carried out together with corresponding examinations of fallout levels in Denmark and Greenland, described in Risø Report No. 549[3] and in Chapter 3 of this report, respectively.

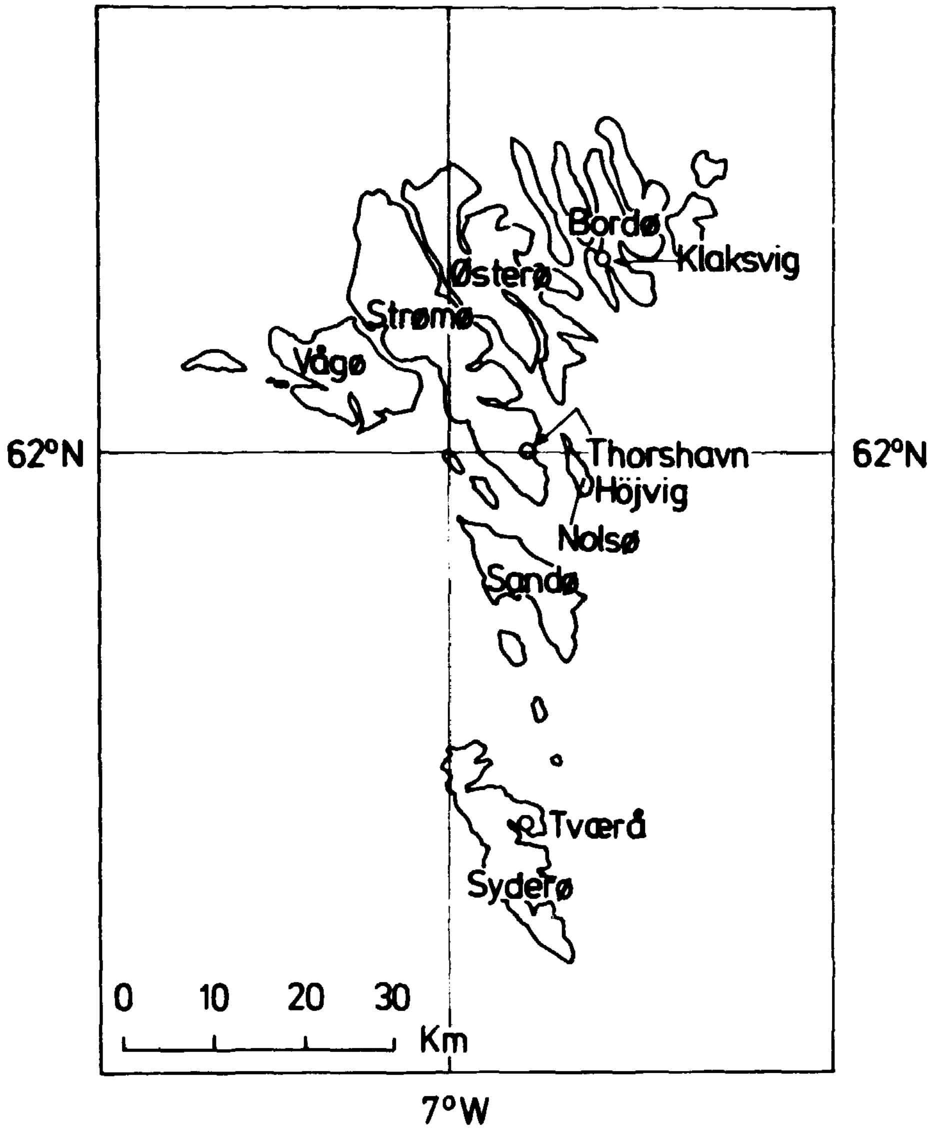


Fig. 2.1. The Faroe Islands.

2.2. Results and Discussion

2.2.1. Strontium-90 and Radiocesium in Faroese Precipitation

Tables 2.2.1.1 and 2.2.1.3 show the ^{90}Sr and radiocesium content, respectively, in precipitation collected at Højvig (near Thorshavn) and Klaksvig in 1987.

The ^{90}Sr fallout in 1987 was about 20 times lower than in 1986. In Denmark the 1987 levels were approximately 26 times less than the 1986 levels[2)].

The mean deposition of ^{137}Cs in the Faroes was 105 Bq m^{-2}. This is a decrease by a factor of 12.5 compared to 1986. In Denmark the levels decreased by a factor of 37[2)]. This suggests a higher resuspension in the Faroes than in Denmark. The ^{137}Cs Chernobyl fallout in 1987 was 3.7 times higher in the Faroes than in Denmark, while the ^{90}Sr fallout was 1.3 times lower.

Table 2.2.1.1. Strontium-90 in precipitation in the Faroes in 1987. (Sampling area: 0.02 m^2)

	Højvig			Klaksvig		
	Bq m^{-3}	Bq m^{-2}	mm precip.	Bq m^{-3}	Bq m^{-2}	mm precip.
Jan-Mar	2.5	0.67	268	0.81 A	0.48 A	598
April-June	1.0 A	0.19 A	191	0.4 A	0.19 A	476
July-Sep	1.65	0.42	252	0.1 B	0.06 B	591
Oct-dec	0.6 B	0.12 B	195	0.1 B	0.08 B	777
1987	$\bar{x}$ 1.55	Σ 1.40	Σ 906	$\bar{x}$ 0.33	Σ 0.81	Σ 2442

Fig. 2.2.1. Accumulated ^{90}Sr at Klaksvig and Højvig calculated from precipitation measurements since 1962. The accumulated fallout by 1962 was estimated from the Danish fallout data (cf. Risø Report No. 527[3], Appendix D) and from the ratio of the ^{90}Sr fallout at the Faroese stations to the fallout in Denmark in the period 1962-1987 (cf. Table 2.2.1.2).

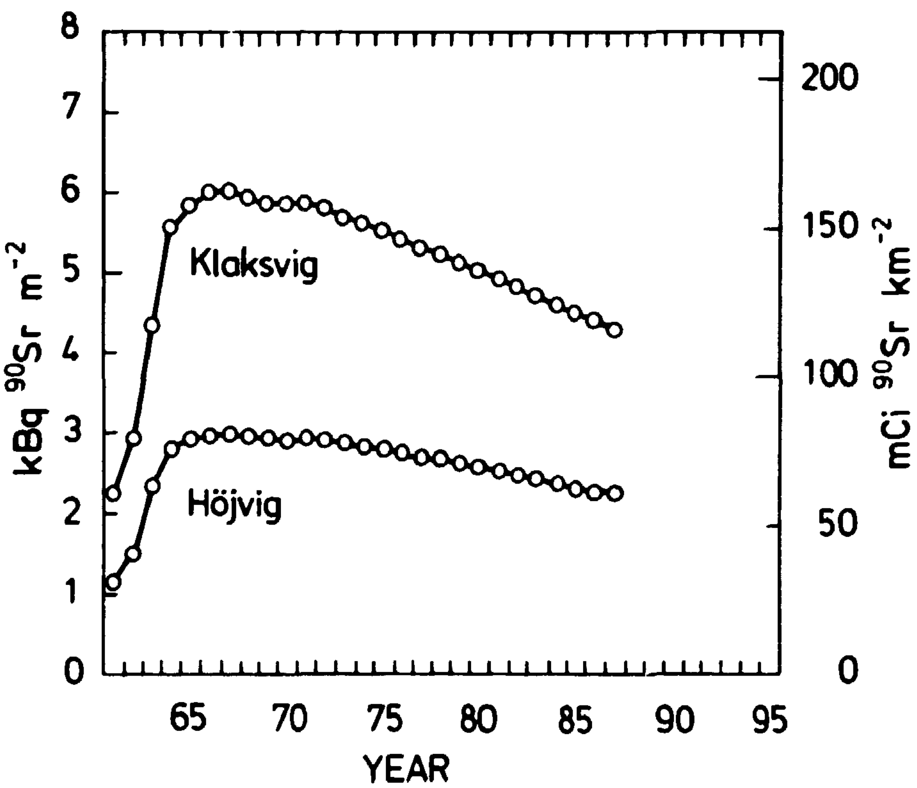


Table 2.2.1.2. Fallout rates and accumulated fallout (Unit: Bq ^{90}Sr m^{-2}) in the Faroes 1950-1987

	Höjvig		Klaksvig	
	d_i	$A_{i(29)}$	d_i	$A_{i(29)}$
1950	1.08	1.06	2.15	2.10
1951	5.21	6.12	10.34	12.14
1952	10.21	15.94	20.27	31.64
1953	25.78	40.74	51.18	80.87
1954	98.02	135.48	194.58	268.94
1955	128.96	258.20	256.00	512.54
1956	159.90	408.22	317.41	810.34
1957	159.90	554.70	317.41	1101.12
1958	221.82	758.18	440.34	1505.05
1959	314.64	1047.48	624.58	2079.33
1960	58.78	1080.14	116.69	2144.16
1961	76.36	1129.19	151.59	2241.52
1962	383.01	1476.48	760.31	2930.93
1963	913.00	2333.05	1503.00	4329.21
1964	544.00	2809.10	1363.00	5557.77
1965	181.00	2919.48	436.00	5852.21
1966	112.00	2959.88	289.00	5996.17
1967	94.70	2982.44	182.00	6032.25
1968	44.00	2954.96	55.50	5943.97
1969	41.10	2925.30	65.10	5867.15
1970	53.60	2908.54	141.00	5866.25
1971	101.00	2938.46	156.00	5880.02
1972	34.40	2902.65	55.10	5794.94
1973	24.20	2857.73	26.50	5683.95
1974	33.80	2823.23	58.80	5607.12
1975	34.40	2790.14	47.80	5521.36
1976	8.88	2732.91	21.60	5412.05
1977	27.40	2695.12	34.40	5317.81
1978	37.30	2667.89	47.60	5238.69
1979	13.90	2618.45	22.20	5136.64
1980	9.55	2565.93	10.29	5025.36
1981	18.37	2523.26	21.80	4927.96
1982	6.33	2469.84	3.91	4815.38
1983	2.75	2414.20	2.24	4703.84
1984	5.53	2362.58	0.87	4593.60
1985	0.98	2307.74	0.59	4485.68
1986	12.80	2264.13	28.00	4407.74
1987	1.40	2212.06	0.81	4304.45

1950-1961: are estimated values based upon HASL data (HASL Appendix 291, 1975) considering that the mean ratio of ^{90}Sr fallout in Denmark to New York was 0.7 in the period 1962-1974 and that the mean ratios of ^{90}Sr fallout in Höjvig to Denmark and Klaksvig to Denmark are 1.39 and 2.76, respectively[5].

Table 2.2.1.3. Radiocesium in precipitation in the Faroes in 1987. (Sampling area: 0.02 m^2)

	Höjvig			Klaksvig		
	^{137}Cs		$^{134}Cs/^{137}Cs$	^{137}Cs		$^{134}Cs/^{137}Cs$
	Bq m^{-3}	Bq m^{-2}		Bq m^{-3}	Bq m^{-2}	
Jan-Mar	250	67	0.43	112	67	0.46
April-June	115	22	0.47	42	20	0.44
July-Sep	111	28	0.38	2.2	1.3	-
Oct-Dec	21	4.1	0.43	0.94	0.73	-
1987	$\bar{x}$ 134	Σ 121		$\bar{x}$ 36	Σ 88	

(Amounts of precipitation are shown in Table 2.2.1.1).

2.2.2. Strontium-90 and Radiocesium in Faroese Grass

Grass samples were collected near Thorshavn in 1987. Table 2.2.2.1 shows the results of the regular samplings. The 1987 ^{137}Cs mean level in grass was one tenth of the 1986 level. The ^{90}Sr levels decreased by a factor of 8 from 1986 to 1987. As compared with Danish grass in 1987[3], we found the ^{90}Sr level (Bq (kg Ca)$^{-1}$) in the Faroese grass in August to be higher by a factor of 2, which is a smaller difference than seen earlier.

Table 2.2.2.2 shows the radionuclide levels in grass collected in July 1987 at various locations in the Faroes (cf. Fig. 2.1). The ^{90}Sr as well as the radiocesium concentrations in these samples were higher than those seen in our routine samples received from Thorshavn. The mean ^{137}Cs concentrations were 30 ± 13.5 Bq ^{137}Cs m^{-2} (± 1 S.D.; N = 4) or 196 ± 95 Bq ^{137}Cs kg^{-1} dry weight or 11950 ± 4560 Bq ^{137}Cs (kg K)$^{-1}$. These levels were, respectively, 23, 15 and 41 times the corresponding Danish ones in July (cf. Risø-R-563, Table 5.10.2[3]). The mean ^{90}Sr concentrations were 6.4 ± 2.7 Bq ^{90}Sr kg^{-1} dry weight (± 1 S.D.; N = 4) or 2800 ± 1540 Bq ^{90}Sr (kg Ca)$^{-1}$. These were, respectively, 3.7 and 2.5 times the corresponding Danish values of September 1987. If we compare $^{134}Cs/^{137}Cs$ in Faroese grass with that in Danish grass we get 0.30 ± 0.06 (± 1 S.D.; N = 4) and 0.37 ± 0.05 (± 1 S.D.; N = 5), respectively. The theoretical Chernobyl $^{134}Cs/^{137}Cs$ in July 1987 was 0.37. This shows us that all radiocesium in Danish grass came from Chernobyl, whereas about 20% of the ^{137}Cs in Faroese grass came from old global fallout in 1987.

Table 2.2.2.1. Strontium-90 and radiocesium in grass from Thorshavn 1987

Month	Bq ^{90}Sr kg^{-1} fresh	Bq ^{90}Sr (kg Ca)$^{-1}$	Bq ^{137}Cs kg^{-1} fresh	Bq ^{137}Cs (kg K)$^{-1}$	$^{134}Cs/^{137}Cs$
June	0.21	330	4.7	1520	0.32
August	1.81	2300	3.4	670	0.28

Table 2.2.2.2. Strontium-90 and radiocesium in Faroese grass samples collected by Risø in July 1987

Location (cf. Fig. 2.1)	Bq ^{90}Sr kg^{-1} dry	Bq ^{90}Sr (kg Ca)$^{-1}$	Bq ^{137}Cs m^{-2}	Bq ^{137}Cs kg^{-1} dry	Bq ^{137}Cs (kg K)$^{-1}$	^{134}Cs/^{137}Cs	% dry matter	kg m^{-2} dry grass
Thorshavn	6.7	4300	19.1	147	16100	0.34	41	0.32
Klaksvig	4.1	1200	46	305	14400	0.34	9	1.70
Vågø	4.6	1890	19.0	92	5700	0.22	23	0.90
Tværå	10.0	4000	37	238	11600	0.28	17	0.93

2.2.3. Strontium-90 and Radiocesium in Faroese Milk

As was done previously[1], weekly samples of fresh milk were obtained from Thorshavn, Klaksvig, and Tværå. Strontium-90 and ^{137}Cs were determined in bulked monthly samples.

If we compare $^{134}/^{137}Cs$ in Faroese milk with the corresponding ratio in Danish[3], the Faroese turns out to be 88% of the Danish. This shows that Faroese milk contains relatively more old global ^{137}Cs fallout than Danish, which is a result of a higher root uptake of the grass (and fodder in general) in the Faroes than in Denmark. From the $^{134}Cs/^{137}Cs$ in Faroese milk compared with the theoretical ratio in Chernobyl debris, it is possible to estimate the content of old global ^{137}Cs fallout in the milk. In 1986 the level was 1350 Bq m^{-3} and in 1987 it was 1310. Compared with the previous years (1982-1985), these levels correspond to an effective half-life of ^{137}Cs in Faroese milk from root uptake by the crops of 2.4 yr (cf. Fig. 2.2.3.4).

In Denmark the ^{137}Cs content in milk decreased by a factor of 1.8[3] from 1986 to 1987. In the Faroese Islands the ^{137}Cs levels increased by a factor of 1.3.

The Faroese ^{137}Cs levels in 1987 were approximately 13 times higher than the Danish.

The Faroese ^{90}Sr milk levels were not influenced significantly by Chernobyl. The mean concentration in 1987 was 89% of the 1986 mean (Table 2.2.3.1).

Tables 2.2.3.3-2.2.3.5 show the analysis of variance of the Bq ^{90}Sr (kg Ca)$^{-1}$, Bq ^{137}Cs (kg K)$^{-1}$, and Bq ^{137}Cs m^{-3} figures, respectively. The highest levels were found in the milk from Tværå and Klaksvig, and the lowest from Thorshavn.

Table 2.2.3.1. Strontium-90 in milk from the Faroes in 1987
(Unit: Bq ^{90}Sr (kg Ca)$^{-1}$)

	Thorshavn	Klaksvig	Tværå	Mean
Jan	57	71	70	66
Feb	57	69	63	63
March	52	80	67	66
April	58	83	62	68
May	58	65	(63)	62
June	63	69	(67)	66
July	71	69	(72)	71
Aug	69	59	54	61
Sept	60	59	(60)	60
Oct	55	71	74	67
Nov	52	60	80	64
Dec	51	59	(56)	55
Mean	59	68	66	64

Figures in brackets were calculated by VAR3[5].

Figure 2.2.3.1 shows the quarterly Bq ^{90}Sr (kg Ca)$^{-1}$ values and Fig. 2.2.3.2 the quarterly Bq ^{137}Cs m^{-3} levels since 1962. Not since 1974 has the Faroese milk contained similar, high ^{137}Cs levels as those observed in the third quarter of 1986.

Figure 2.2.3.3 shows a comparison between the ^{90}Sr and ^{137}Cs levels in Faroese- and Danish-produced milk. It is evident that indirect contamination plays an important role for the ^{137}Cs levels in the Faroes, because the ratio of ^{137}Cs in Faroese to Danish milk increases when the fallout rate decreases. It decreases when the fallout rate (as has happened after Chernobyl) increases. The ratios of the ^{90}Sr levels in Faroese to Danish milk have shown a slight tendency to decrease through the years.

In July a special milk sampling from Faroese farms was carried out by Risø. Table 2.2.3.6 shows the results.

Compared with the ordinary sampling (Table 2.2.3.2), the whole milk contained nearly two times as much from Thorshavn and Klaksvig, whereas whole milk and consumers milk agreed for Tværå. The $^{134}Cs/^{137}Cs$ in whole milk was a little lower than in consumers milk.

Compared with the grass levels (Table 2.2.2.2), the Faroese milk contained 0.95 ± 0.25 times (± 1 S.D.; N = 4) the Bq ^{137}Cs (kg K)$^{-1}$ in grass. Table 2.2.3.7 shows that the ratio of the concentrations in milk to that in grass was approximately 0.3 for ^{137}Cs as well as for ^{134}Cs. This corresponds to the ratio observed earlier in Denmark[5] and it shows that global fallout and Chernobyl debris behaved similarly with regard to radiocesium uptake in milk.

Table 2.2.3.2. Radiocesium in milk from the Faroes in 1987

	Thorshavn			Klaksvig			Tværå			Mean		
Month	Bq ^{137}Cs m^{-3}	Bq ^{137}Cs (kg K)$^{-1}$	^{134}Cs/^{137}Cs	Bq ^{137}Cs m^{-3}	Bq ^{137}Cs (kg K)$^{-1}$	^{134}Cs/^{137}Cs	Bq ^{137}Cs m^{-3}	Bq ^{137}Cs (kg K)$^{-1}$	^{134}Cs/^{137}Cs	Bq ^{137}Cs m^{-3}	Bq ^{137}Cs (kg K)$^{-1}$	^{134}Cs/^{137}Cs
Jan	6200	3600	0.42	8900	5300	0.29	13900	7900	0.38	9600	5600	0.36
Feb	5800	3400	0.39	7000	3900	0.38	12100	8000	0.40	8300	5100	0.39
March	6200	3700	0.40	8000	4700	0.39	11500	6900	0.35	8500	5100	0.38
April	5700	3700	0.35	10300	5700	0.36	11400	7100	0.37	9100	5500	0.36
May	6400	3800	0.34	7500	4300	0.35	(15000)	(9300)	(0.33)	9600	5800	0.34
June	5600	3600	0.34	5200	3000	0.32	(11600)	(7000)	(0.32)	7500	4400	0.33
July	6200	3600	0.29	6200	3700	0.33	(13300)	(8400)	(0.30)	8600	5300	0.31
Aug	5700	3600	0.24	4000	2300	0.28	12400	7900	0.25	7400	4600	0.26
Sept	5000	3000	0.25	4900	2800	0.34	(10600)	(6700)	(0.28)	6800	4200	0.29
Oct	3400	1890	0.24	4700	2600	0.32	10300	6500	0.26	6200	3600	0.27
Nov	3000	1760	0.30	3100	1610	0.28	10800	6500	0.27	5600	3300	0.28
Dec	[illegible]	1750	0.28	3100	1810	0.33	(6400)	(4100)	(0.29)	4100	2500	0.30
Mean	5200	3100	-	6100	3500	-	11600	7200	-	7600	4600	-

Figures in brackets were calculated from VAR3[5].

Table 2.2.3.3. Analysis of variance of ln Bq ^{90}Sr (kg Ca)$^{-1}$ in Faroese milk in 1987 (from Table 2.2.3.1)

Variation	SSD	f	s^2	v^2	P
Between months	0.095	11	0.009	0.54	-
Between locations	0.152	2	0.076	4.80	>97.8%
Remainder	0.269	17	0.016		

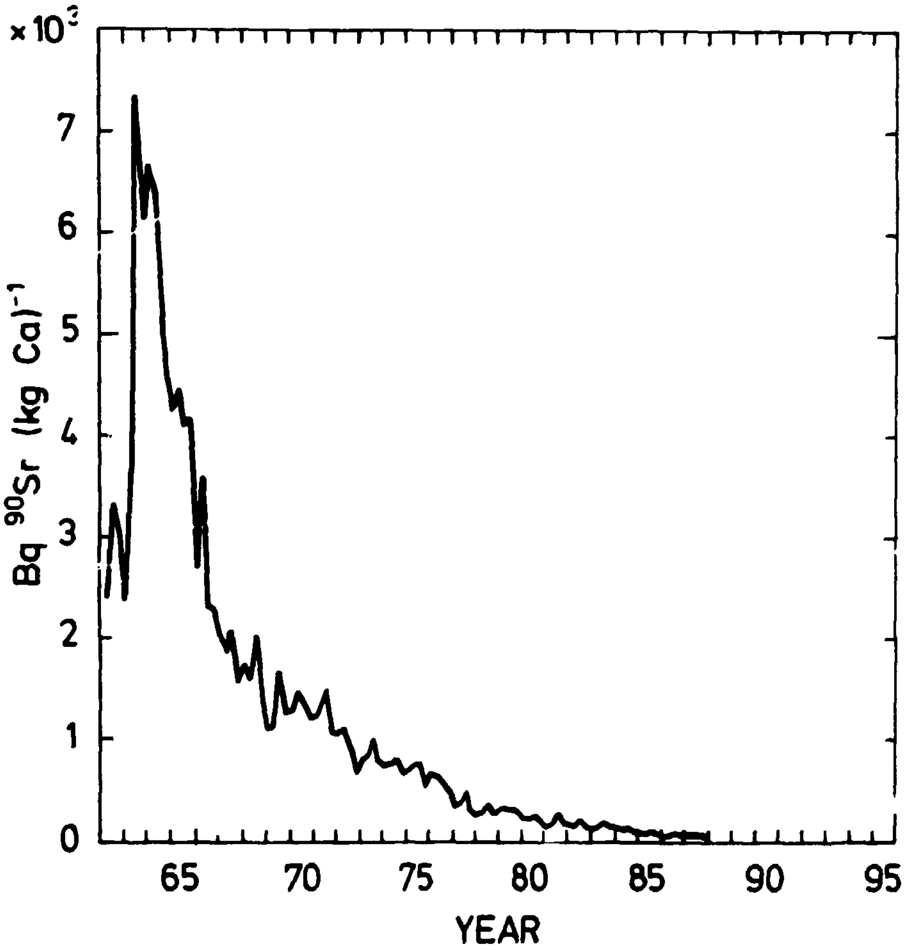
Table 2.2.3.4. Analysis of variance of ln Bq ^{137}Cs (kg K)$^{-1}$ in Faroese milk in 1987 (from Table 2.2.3.2)

Variation	SSD	f	s^2	v^2	P
Between months	2.20	11	0.20	4.31	>99.6 %
Between locations	3.37	2	1.68	36.4	>99.95%
Remainder	0.79	17	0.046		

Table 2.2.3.5. Analysis of variance of ln Bq ^{137}Cs m^{-3} in Faroese milk in 1987 (from Table 2.2.3.2)

Variation	SSD	f	s^2	v^2	P
Between months	2.10	11	0.191	4.60	>99.7 %
Between locations	2.91	2	1.46	35.0	>99.95%
Remainder	0.71	17	0.042		

Fig. 2.2.3.1. Strontium-90 in Faroese milk, 1962-1987.



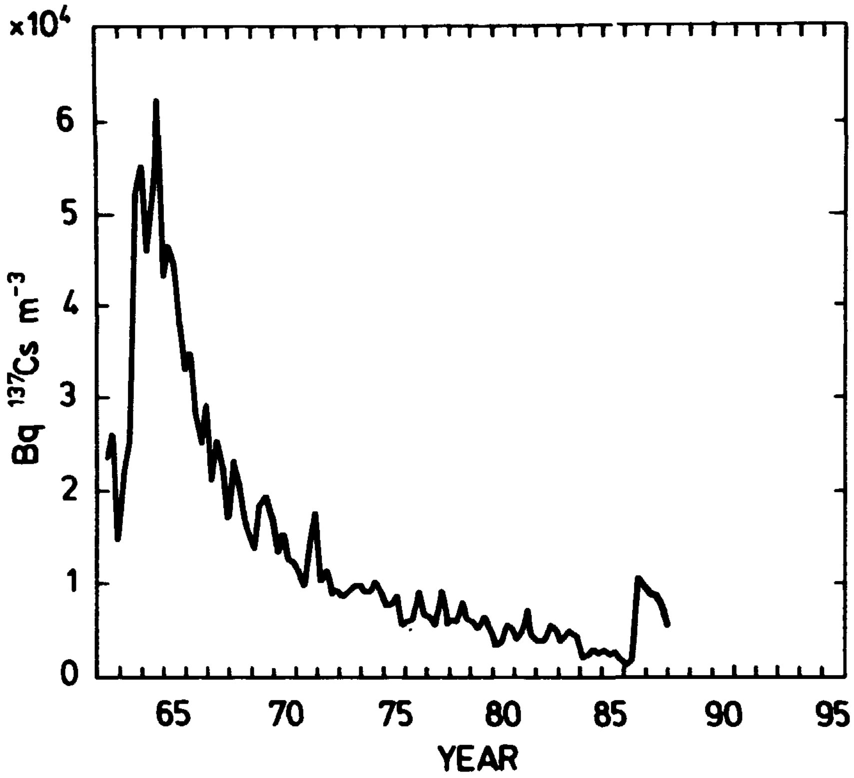
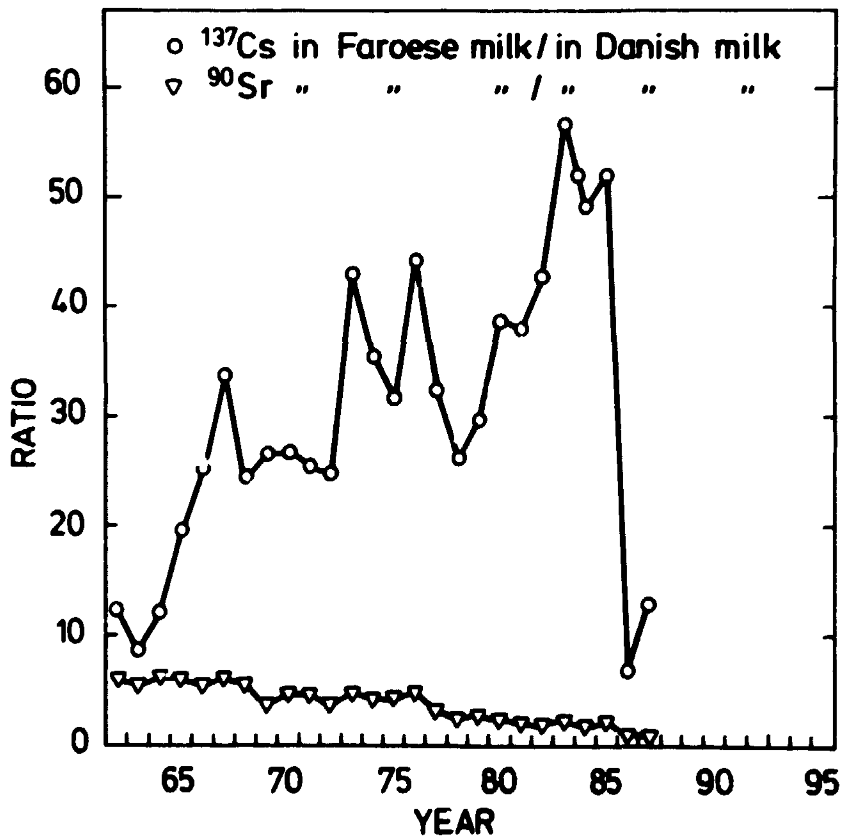


Fig. 2.2.3.2. Cesium-137 in Faroese milk, 1962-1987.

Fig. 2.2.3.3. A comparison between Faroese and Danish milk levels, 1962-1987.



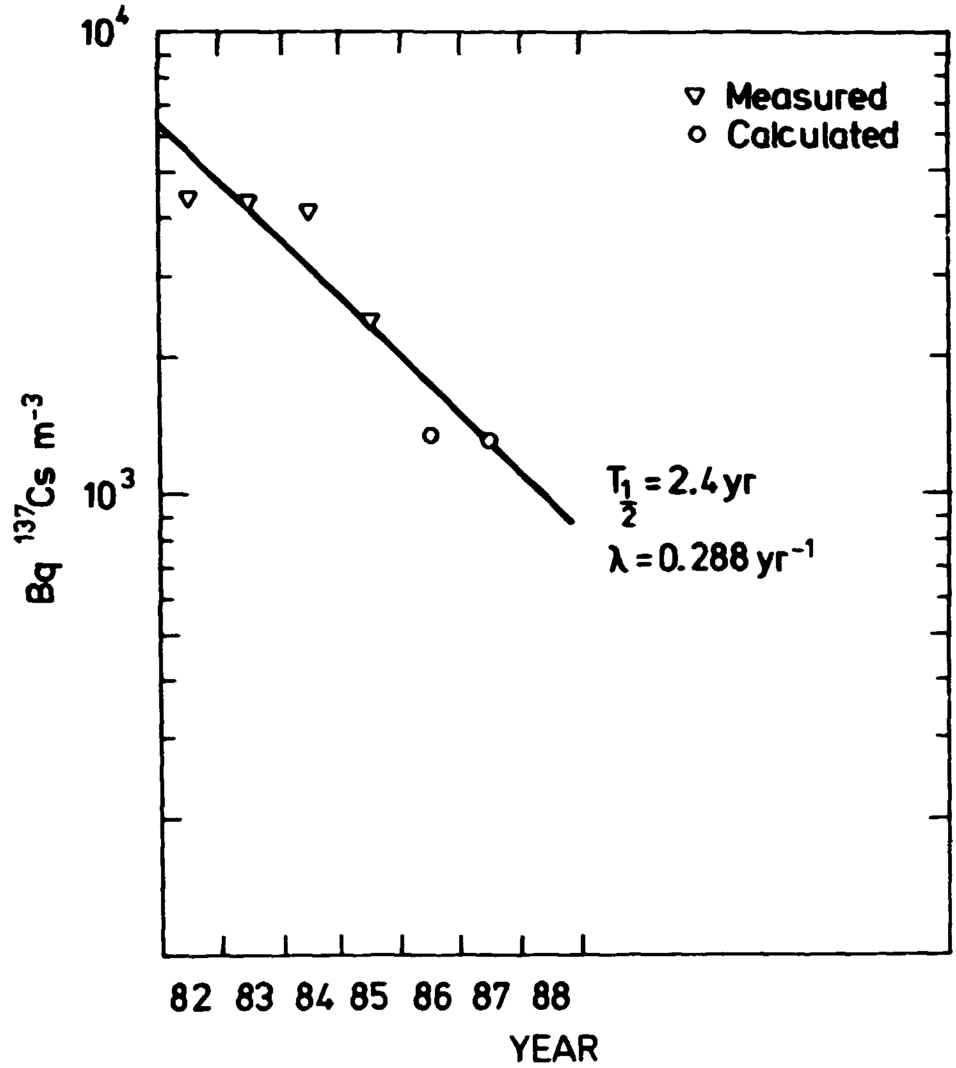


Fig. 2.2.3.4. The calculated global fallout ^{137}Cs concentrations (Bq m^{-3}) in Faroese milk 1982-1987. The levels in 1986 and 1987 were calculated from the $^{134}Cs/^{137}Cs$ assuming this ratio to have been zero in global fallout and 0.55 in Chernobyl debris on April 26, 1986.

Table 2.2.3.6. Radiocesium in whole milk collected by Risø at Faroese farms in July 1987

Location (cf. Fig. 2.1)	Bq ^{137}Cs m^{-3}	Bq ^{137}Cs (kg K)$^{-1}$	$\frac{^{134}Cs}{^{137}Cs}$
Vågø	4900	2900	0.28
Thorshavn	12300	7700	0.29
Klaksvig	12100	7800	0.29
Tværå	15300	9500	0.29

Table 2.2.3.7. Radiocesium in Faroese milk (Bq l^{-1}) divided by radiocesium in Faroese grass (Bq kg^{-1} fresh weight) in July 1987 (cf. Tables 2.2.2.2 and 2.2.3.6)

Location	^{134}Cs	^{137}Cs
Vågø	0.30	0.23
Thorshavn	0.17	0.20
Klaksvig	0.37	0.44
Tværå	0.39	0.38
Mean	0.31	0.31
S.E.	0.05	0.06

2.2.4. Strontium-90 and Radiocesium in Faroese Terrestrial Animals

If the $^{134}Cs/^{137}Cs$ in lamb is compared with the theoretical ratios in Chernobyl debris (Table 2.2.4), it appears that about 80% of the ^{137}Cs in the lamb samples from 1987 came from Chernobyl. This is a little less than found in Faroese milk (84%) from 1987.

The mean contents in Faroese lambs in 1987 were 0.22 Bq ^{90}Sr kg^{-1} meat and 107 Bq ^{137}Cs kg^{-1} meat and in bone 1020 Bq ^{90}Sr (kg $Ca)^{-1}$. Cs-137 measured in lamb in 1987 was similar to the mean of measurements made in 1986.

Fig. 2.2.4.1. Strontium-90 (Bq (kg $Ca)^{-1}$)) in lamb bone collected in the Faroes, 1962-1987.

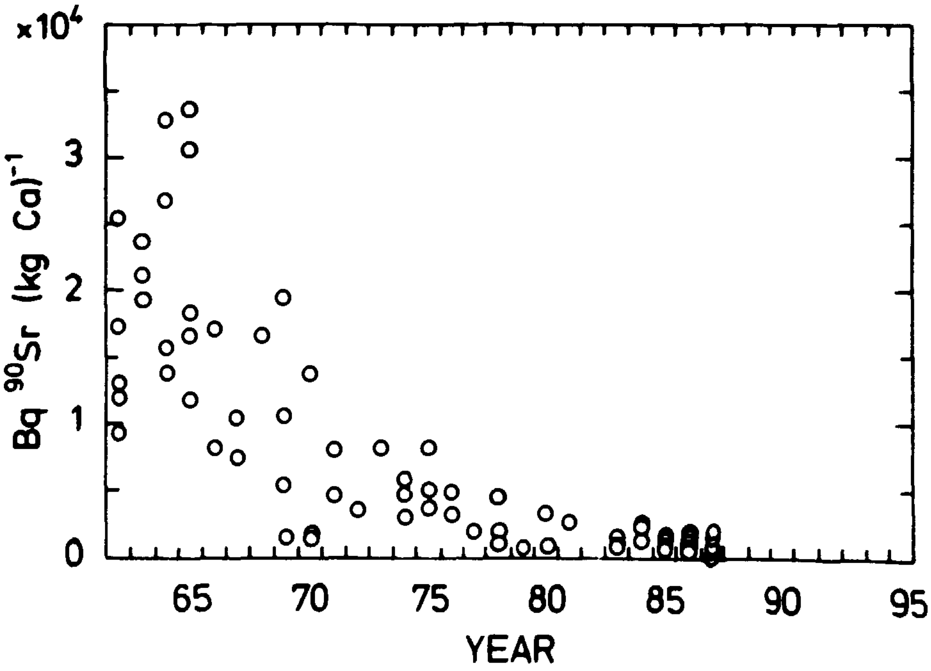
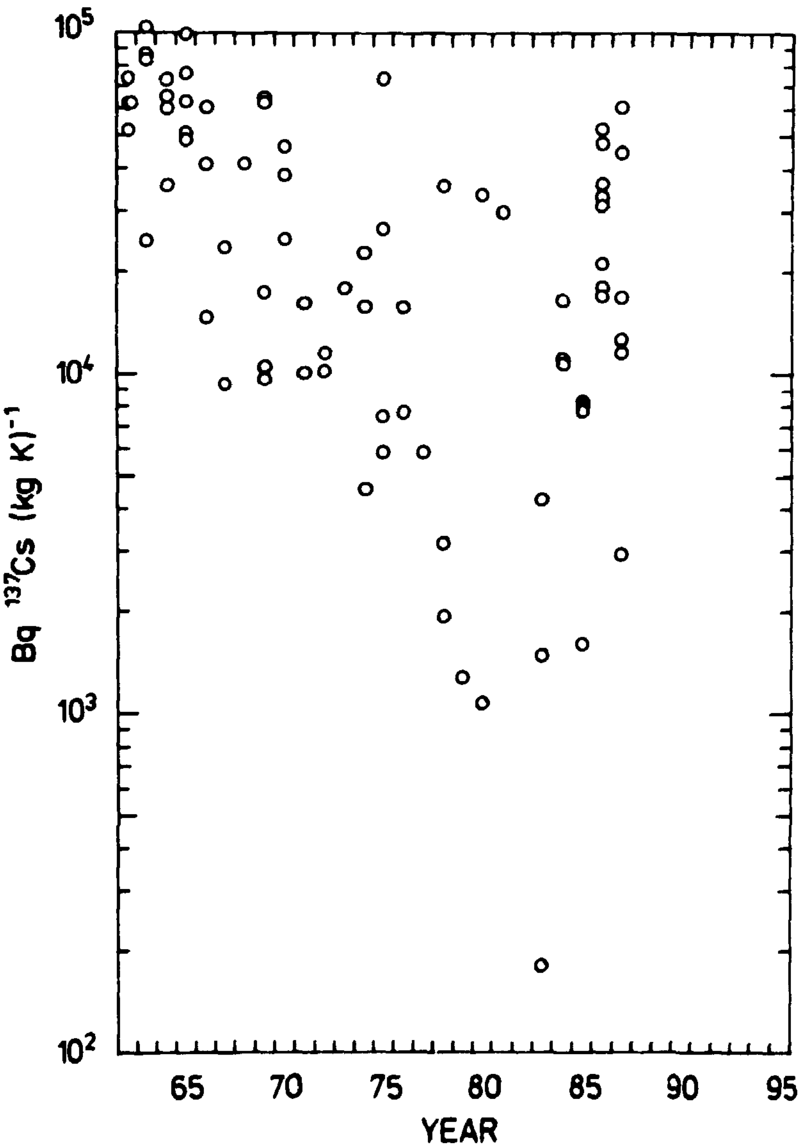


Table 2.2.4. Radionuclides in lamb collected in the Faroes in 1987

Location	Position N	Position W	Month	Lamb meat Bq ^{90}Sr kg^{-1}	Lamb meat Bq ^{137}Cs kg^{-1}	Lamb meat Bq ^{137}Cs $(kg\ K)^{-1}$	$\frac{^{134}Cs}{^{137}Cs}$	Bone Bq ^{90}Sr $(kg\ Ca)^{-1}$	Theoretical $\frac{^{134}Cs}{^{137}Cs}$ in Chernobyl debris
Vidareide	62°22'	6°32'	Jan	-	35	-	0.43	280	0.44
Skuvoy	61°46'	6°49'	Jan	-	12.8	-	0.45	640	0.44
Øravik	61°32'	6°48'	Feb	-	126	-	0.38	-	0.43
Kollefjord	62°06'	6°57'	Oct	0.114	249	62000	0.16	1610	0.35
Klaksvig			Oct	0.038	42	12800	0.26	680	0.35
Tværå			Oct	0.50	178	46000	0.24	2100	0.35
Thorshavn			July	-	-	-	-	800	-

Fig. 2.2.4.2. Cesium-137 (Bq (kg K)$^{-1}$) in lamb meat collected in the Faroes, 1962-1987.



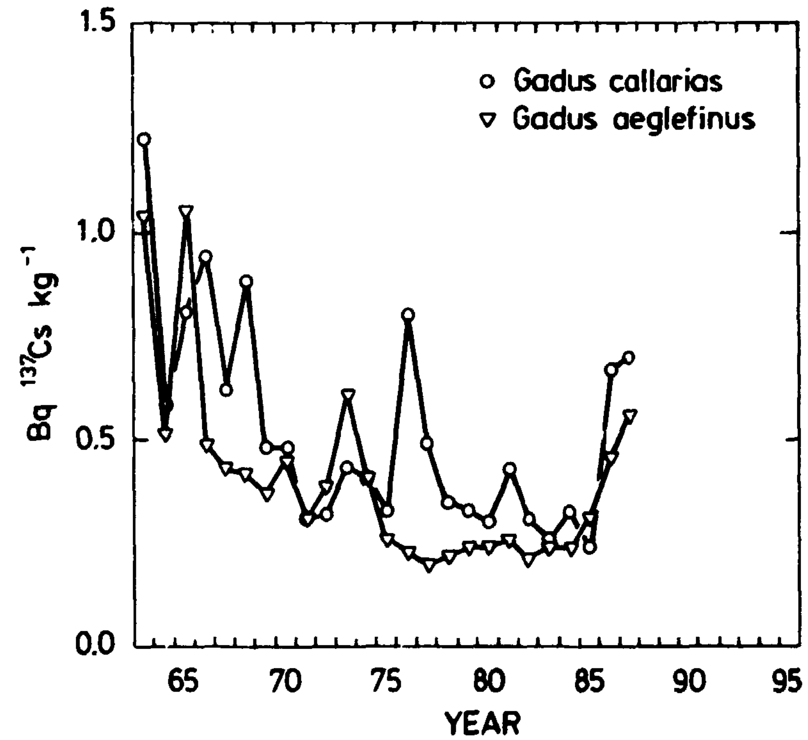
2.2.5. Strontium-90 and Radiocesium in Faroese Sea Animals

Table 2.2.5.1 shows the ^{137}Cs levels in fish collected in 1987 in the Faroes. The mean levels in Gadus aeglefinus and Gadus callarias were 0.63 Bq ^{137}Cs kg^{-1} and 0.00077 Bq ^{90}Sr kg^{-1}. Chernobyl ^{137}Cs was detectable in most fish samples. On the average two-thirds of the ^{137}Cs in marine fish came from Chernobyl in 1987, but the variation between samples was large.

Table 2.2.5.1. Strontium-90 and radiocesium in fish flesh from the Faroes in 1987

Sampling month	Species	Sample type	Bq ^{90}Sr kg^{-1}	Bq ^{90}Sr $(kg\ Ca)^{-1}$	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs $(kg\ K)^{-1}$	$^{134}Cs/^{137}Cs$
March	Gadus callarias	Cod	0.00037 A	4.8 A	1.00	270	0.33
June	"				0.27	76	0.13
Sept	"		0.00114	12.2	0.93	260	0.27
Dec	"				0.61	191	0.29
1987			0.00076	8.5	0.70	199	
March	Gadus aeglefinus	Haddock	0.00064 A	7.4 A	0.75	220	0.35
June	"				0.85	240	0.28
Sept	"		0.00090	11.4	0.165	56	-
Dec	"				0.46	136	0.26
1987			0.00077	9.4	0.56	163	

Fig. 2.2.5.1. Cesium-137 levels in meat of cod (Gadus callarias) and haddock (Gadus aeglefinus) collected in the Faroes, 1962-1987.



In Table 2.2.5.2 the activity content of a few other marine samples is shown. Two-thirds of the ^{137}Cs in the whale sample came from Chernobyl.

Table 2.2.5.2. Strontium-90 and radiocesium in various marine animals collected in July 1987

Species	Sample	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs $(kg\ K)^{-1}$	^{134}Cs / ^{137}Cs	Bq ^{90}Sr $(kg\ Ca)^{-1}$
Whale	flesh	0.80	400	0.25	B.D.L.
Puffin (June)	flesh	0.146 A	47	-	-
" "	bone	2.9	-	-	-
Blue mussels	flesh	<0.8	<800	-	6 B
" "	shell	<0.25	-	-	1.3 B

2.2.6. Strontium-90, Cesium-137 and Tritium in Faroese Drinking Water and Other Fresh Waters

Drinking-water samples were collected as previously, but the samples were combined prior to the analysis as shown in Table 2.2.6.1. As in previous years, drinking water from Thorshavn contained more ^{90}Sr than that from Klaksvig and Tværå (cf. the explanation in Risø Report No. 181[1]). The mean level in 1987 was 2.3 Bq ^{90}Sr m^{-3} (0.063 pCi l^{-1}), i.e. a little lower compared to 1986.

Figure 2.2.6.1 shows the annual mean levels of ^{90}Sr in drinking water from the three locations since 1962.

In Table 2.2.6.2 it appears that $82 \pm 7\%$ (± 1 S.D.; N = 3) of the ^{137}Cs in Faroese drinking water was from Chernobyl. Although the ^{137}Cs concentrations in Tværå were 3.3 times higher than in Klaksvig, the relative contribution from Chernobyl was only a factor of 1.14 times higher at Tværå than at Klaksvig. A sample of untreated raw water from Thorshavn contained 5.0 Bq ^{137}Cs m^{-3} and 1.7 A Bq ^{134}Cs m^{-3}, which was not significantly different from the concentrations in the Thorshavn drinking water.

In Table 2.2.6.3 concentrations in stream water are shown. The Chernobyl percentage of ^{137}Cs was $70 \pm 4\%$ (± 1 S.D.; N = 3), i.e. similar to that in Faroese drinking water.

Lake water (Table 2.2.6.4) showed $53 \pm 15\%$ (± 1 S.D.; N = 2) ^{137}Cs from Chernobyl, which may be a little lower than the contributions seen in drinking water and stream water.

The ^{137}Cs concentrations in the various fresh water samples varied significantly between locations, but apparently not between water types.

Compared with the mean concentrations in rain water from the first half of 1987, the fresh water samples from July 1987 contained about 5% of the ^{137}Cs found in the rain. This shows that also Faroese soil, despite its low mineral content, retains radiocesium quite efficiently from the rain.

All drinking water samples collected in the Faroes in 1987 contained less than 2 Bq ^{3}H l^{-1}.

Table 2.2.6.1. Strontium-90 and radiocesium in drinking water from the Faroes in 1987. (Unit: Bq m^{-3})

Month	Thorshavn ^{90}Sr	Thorshavn ^{134}Cs	Thorshavn ^{137}Cs	Klaksvig ^{90}Sr	Klaksvig ^{134}Cs	Klaksvig ^{137}Cs	Tværå ^{90}Sr	Tværå ^{134}Cs	Tværå ^{137}Cs
Jan-June	4.4		5.7	0.81		2.1 A	2.6		3.1
July-Aug	3.2		3.6	0.85		2.4 A	2.2		2.2 A
1987	3.8	1.55	4.7	0.83	0.63	2.2	2.4	0.82	2.6

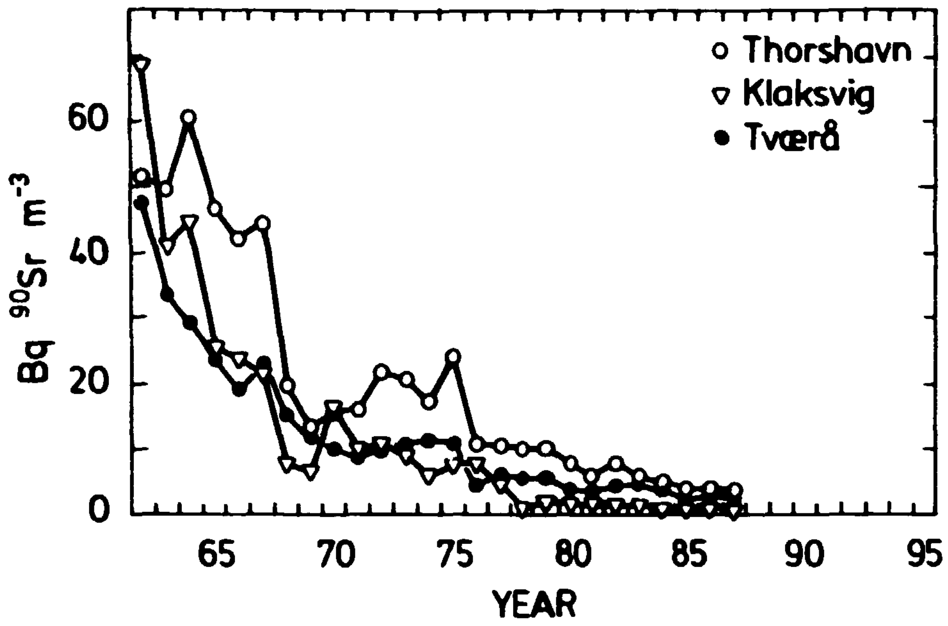


Fig. 2.2.6.1. Strontium-90 in drinking water from the Faroes, 1962-1987.

Table 2.2.6.2. Radiocesium and tritium in drinking water from the Faroes collected by Risø in July 1987

Location	^{134}Cs Bq m^{-3}	^{137}Cs Bq m^{-3}	$^{134}Cs/^{137}Cs$	^{3}H kBq m^{-3}
Sørvaag/Vaagø	2.4	8.7	0.27	B.D.L.
Thorshavn/Strømø	1.3 A	5.5	0.24	0.9 ± 0.1
Klaksvig/Bordø	0.91	3.2	0.29	1.1 ± 0.2
Tværå/Sydero	3.0	10.4	0.29	1.3 ± 0

Table 2.2.6.3. Radiocesium and tritium in stream water from the Faroes collected by Risø in July 1987

Location	^{134}Cs Bq m^{-3}	^{137}Cs Bq m^{-3}	$^{134}Cs/^{137}Cs$	^{3}H kBq m^{-3}
Sanda, south of Thorshavn	1.4	5.8	0.25	B.D.L.
Haydalsa, north of Thorshavn	2.7	10.6	0.26	B.D.L.
Stora/Syderø	1.7	5.8	0.28	B.D.L.

Table 2.2.6.4. Radiocesium and tritium in lake water from the Faroes collected by Risø in July 1987

Location	^{134}Cs Bq m^{-3}	^{137}Cs Bq m^{-3}	$^{134}Cs/^{137}Cs$	^{3}H kBq m^{-3}
Leynavatn/Strømø	0.90	3.7	0.24	B.D.L.
Sørvagsvatn/Vaagø	1.6 A	9.9	0.16	B.D.L.

2.2.7. Strontium-90 and Radiocesium in Miscellaneous Faroese Samples

2.2.7.1. Faroese Soil

In July 1987 Risø collected 4 soil samples in the Faroes (cf. Tables 2.2.7.1.1-2.2.7.1.4). The mean Chernobyl ^{137}Cs deposition was 1900 ± 640 Bq ^{137}Cs m^{-2} (± 1 S.D.; N = 4). This mean agreed with that of the more extensive Faroese soil sampling in 1986 (Risø-R-564)[4]. The samples were as far as possible

Table 2.2.7.1.1. Radiocesium in soil collected at Vaagø by Risø (Vatns oyrar) in July 1987

Layer in cm	^{137}Cs Bq m^{-2}	^{137}Cs Bq kg^{-1}	^{134}Cs/^{137}Cs	g K kg^{-1}	Chernobyl ^{137}Cs Bq m^{-2}
0-5	2400	182	0.194	2.8	1270
5-10	1210	93	0.019	2.1	62
10-20	1480	53		1.85	
20-30	310	9.1		1.68	
30-40	91	4.9		1.31	
40-50	65	1.19		2.2	

Table 2.2.7.1.2. Radiocesium in soil from Thorshavn/Højvig collected by Risø in July 1987

Layer in cm	^{137}Cs Bq m^{-2}	^{137}Cs Bq kg^{-1}	^{134}Cs/^{137}Cs	g K kg^{-1}	Chernobyl ^{137}Cs Bq m^{-2}
0-5	4300	410	0.130	3.6	1530
5-10	3700	200	0.006	3.5	60
10-20	550	19.4		3.8	
20-30	300	6.8		3.2	
30-40	104	2.4		2.8	
40-50	97	1.59		2.7	

Table 2.2.7.1.3. Radiocesium in soil from Bordø, Arnefjord collected by Risø in July 1987 (Klaksvig)

Layer in cm	^{137}Cs Bq m^{-2}	^{137}Cs Bq kg^{-1}	^{134}Cs/^{137}Cs	g K kg^{-1}	Chernobyl ^{137}Cs Bq m^{-2}
0-5	3200	300	0.203	1.87	1760
5-10	280	87	0.062	1.55	47
10-20	350	20	0.074	1.47	71

Table 2.2.7.1.4. Radiocesium in soil from Syderø, Tværå collected by Risø in July 1987

Layer in cm	^{137}Cs Bq m^{-2}	^{137}Cs Bq kg^{-1}	^{134}Cs/^{137}Cs	g K kg^{-1}	Chernobyl ^{137}Cs Bq m^{-2}
0-5	4800	540	0.207	2.6	2700
5-10	1560	118	0.023	1.58	97
10-20	630	28		1.31	

collected to a depth of 50 cm. Chernobyl radiocesium was normally not detectable below 10 cm. However, in the Klaksvig sample ^{134}Cs was found in the 10-20 cm layer also. Global fallout ^{137}Cs had possibly penetrated deeper than 50 cm, at least at Vaagø and Thorshavn. The year total ^{137}Cs deposit at the 4 locations was 6400 ± 2200 Bq m^{-2} (± 1 S.D.; N = 4). Thus, Chernobyl contributed with 30% to the total ^{137}Cs in Faroese soil.

The ratios of the drinking water concentrations (Table 2.2.6.2) to the 0-5 cm soil layer concentrations are calculated for ^{137}Cs from global fallout and Chernobyl. The latter ratios are nearly 3 times higher than the former. This may be because the global fallout ^{137}Cs has been fixed stronger to the soil than the Chernobyl ^{137}Cs, as it has been longer in the soil. It could also be because relatively more of the Chernobyl ^{137}Cs is found in the soil surface. Finally, some of the activity from Chernobyl may have come directly from the rain without any contact with the soil minerals.

2.2.7.2. Faroese Sea Water

The ^{137}Cs mean concentration in Faroese sea water from Thorshavn was 3.5 Bq m^{-3}. The ^{90}Sr level was 1.73 Bq m^{-3}. The Chernobyl signal had thus disappeared in 1987. In Table 2.2.7.2.2 traces of ^{134}Cs from Chernobyl were present in two sea water samples containing some fresh water.

Table 2.2.7.2.1. Strontium-90 and cesium-137 in Faroese surface sea water collected at Thorshavn (62°02'N 06°47'W) in 1987. (Unit: Bq m^{-3})

Sampling date	^{90}Sr	^{137}Cs	Salinity in ‰
April	1.96	3.7	-
August	1.65	3.7	34.2
December	1.57	3.1	34.9

Fig. 2.2.7.2. Strontium-90 and cesium-137 in Faroese sea water 1962-1987.

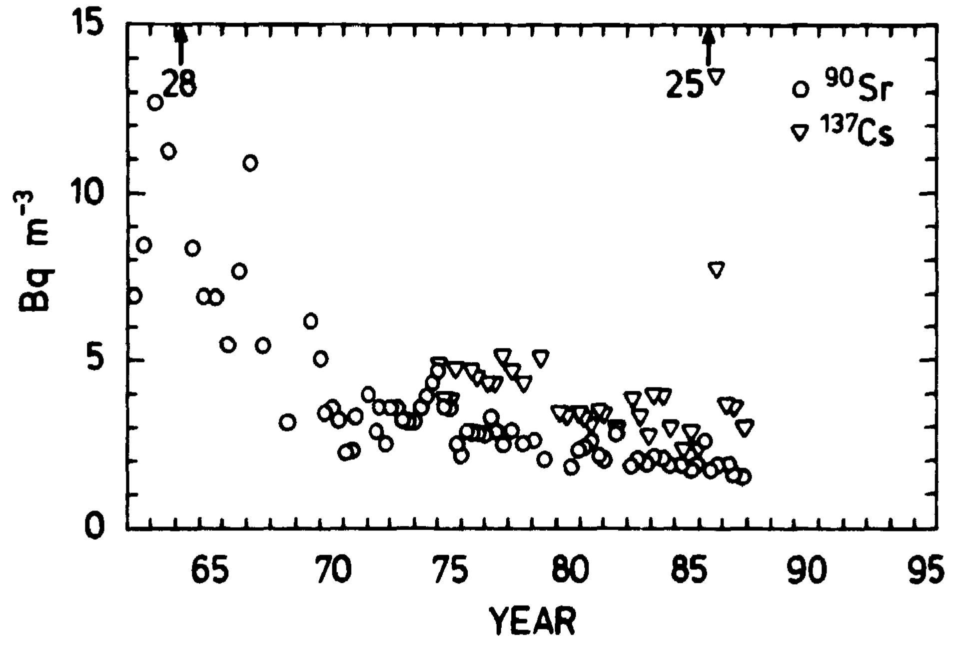


Table 2.2.7.2.2. Radiocesium in Faroese surface sea water collected by Risø in July 1987. (Unit: Bq m^{-3})

Location	Position N W	^{137}Cs	$\frac{^{134}Cs}{^{137}Cs}$	Salinity in ‰
Sørvåg/Vågø	62°05' 7°19'	3.3	-	34.5
Thorshavn/Strømø	62°00' 6°46'	3.6	-	34.6
Arnefjord/Bordø		4.5	0.17 B	29.0
Trangisvåg/Syderø		5.1	0.19	17.1

2.2.7.3. Faroese Sea Plants

As for sea water, the Chernobyl signal had nearly disappeared from Faroese sea plants in 1987. The ^{137}Cs levels in Laminaria from Thorshavn in 1987 were 3-4 times lower than those in 1986, which corresponds to the decrease in the sea water concentrations.

If we assume the concentration of ^{99}Tc in Fucus vesiculosus relative to sea water to be 10^5, we may estimate the water concentration as 0.013 ± 0.002 Bq ^{99}Tc m^{-3} (± 1 S.E.; N = 4), i.e. a factor of 100 lower than in the Norwegian coastal current at Utsira (cf. Table 4.1).

Table 2.2.7.3.1. Radionuclides in Faroese seaweed collected in 1987 (Unit: Bq kg^{-1} dry weight)

Species	Date	^{90}Sr	^{106}Ru	^{110m}Ag	^{134}Cs	^{137}Cs	K g kg^{-1}	Ca g kg^{-1}
Fucus disticus	April	0.22	3.6 A	1.05	0.55	1.59	31.5	11.2
Laminaria digitata	April	0.39				1.17 A	62.2	15.8
Fucus vesiculosus	Aug	0.196				0.65	30.4	11.0
Laminaria digitata	Aug	0.24		0.5 B		0.56	27.9	13.4

Fig. 2.2.7.3. Strontium-90 (Bq (kg Ca)$^{-1}$) in sea plants collected at Thorshavn, 1962-1987.

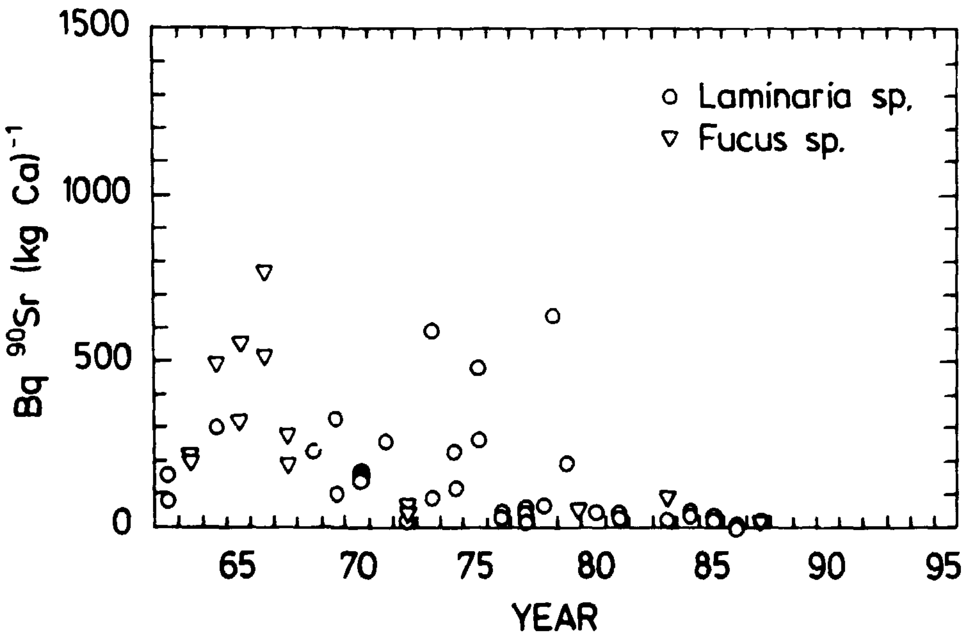


Table 2.2.7.3.2. Radionuclides in Faroese Fucus vesiculosus collected by Risø in July 1987. (Unit: Bq kg^{-1} dry weight)

Location	^{90}Sr	^{99}Tc	^{110m}Ag	^{134}Cs	^{137}Cs	K g kg^{-1}	Ca g kg^{-1}
Sørvaag (Vågø)	0.41	0.88	1.27 A		0.99 A	33.3	19.1
Nolsøfjord (Strømø)	0.24	1.04			1.36	28.8	12.4
Arnefjord (Bordø)		1.36		0.65	2.16	26.3	
Trangisvaag (Sydero)	0.44	1.78			1.55 A	26.5	13.9

2.2.7.4. Faroese Vegetables

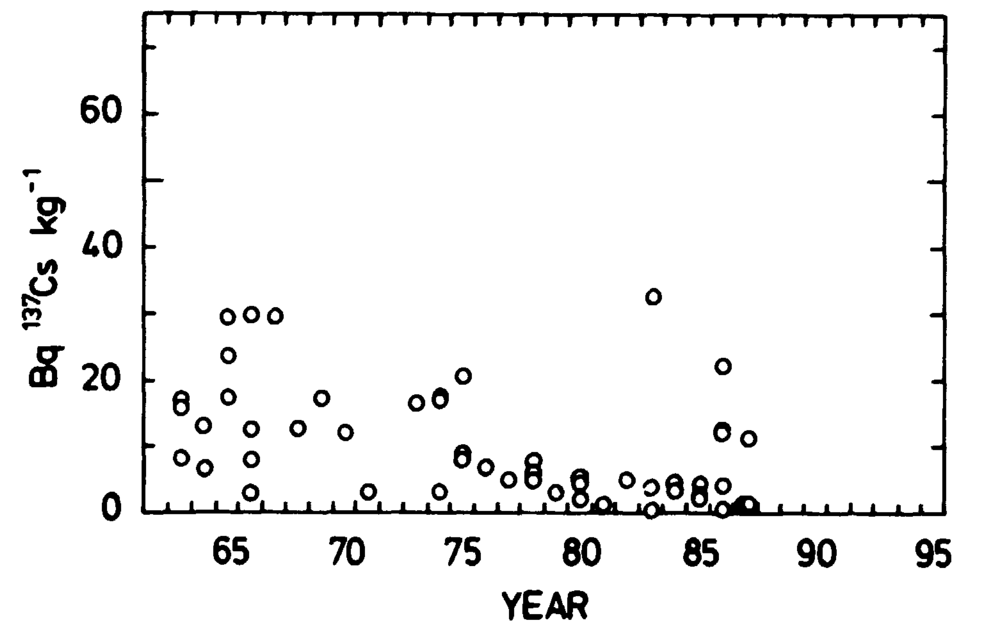
Five samples of potatoes were analysed in 1987. The mean content was 0.059 Bq ^{90}Sr kg^{-1} (1370 Bq ^{90}Sr (kg Ca)$^{-1}$) and 3.6 Bq ^{137}Cs kg^{-1} (890 Bq ^{137}Cs (kg K)$^{-1}$). 74 ± 11% (±1 S.E.; N = 5) of the ^{137}Cs in Faroese potatoes came from Chernobyl in 1987.

Rhubarbs (Table 2.2.7.4.3) contained higher ^{90}Sr but lower ^{137}Cs concentrations than potatoes.

Table 2.2.7.4.1. Radionuclides in Faroese potatoes collected in November 1987

Location	Month	Bq ^{90}Sr kg^{-1}	Bq ^{90}Sr (kg Ca)$^{-1}$	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs (kg K)$^{-1}$	^{134}Cs/^{137}Cs
Thorshavn	November	0.086	2100	1.44	380	0.124
Klaksvig	November	0.086	1080	0.96	240	0.27
Tværå	November	0.035	1450	11.31	2900	0.28

Fig. 2.2.7.4.1. Cesium-137 in Faroese potatoes, 1962-1987.



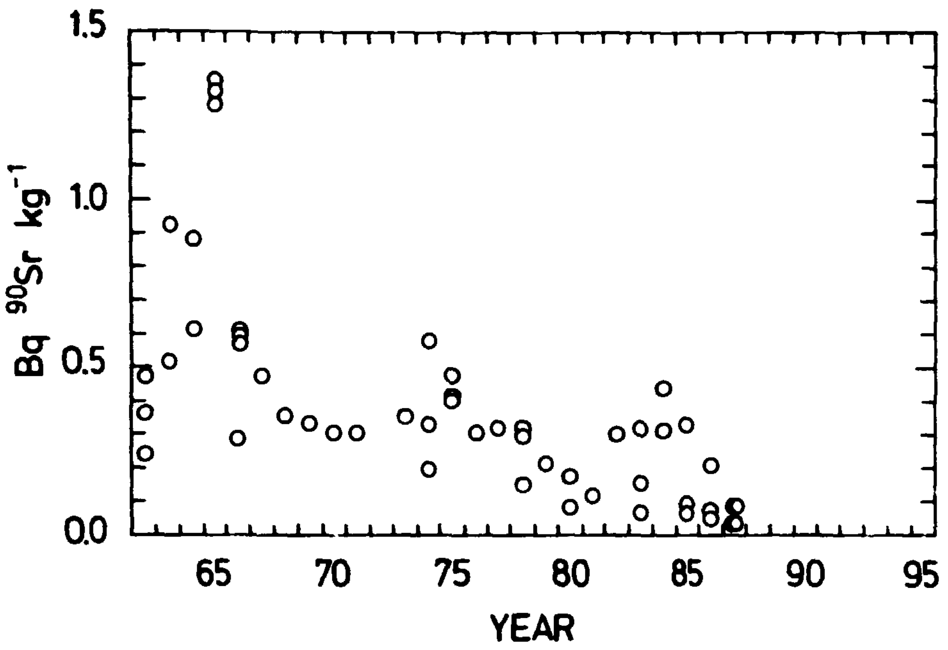


Fig. 2.2.7.4.2. Strontium-90 in Faroese potatoes, 1962-1987.

Table 2.2.7.4.2. Radionuclides in Faroese potatoes collected by Risø in July 1987 (old potatoes from 1986)

Location	Bq ^{90}Sr kg^{-1}	Bq ^{90}Sr $(kg\ Ca)^{-1}$	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs $(kg\ K)^{-1}$	$\frac{^{134}Cs}{^{137}Cs}$
Thorshavn*			4.0	810	0.26
Vaag-Lobra road	0.028	830	0.42	96	0.38

*Only washed, not peeled.

Table 2.2.7.4.3. Radionuclides in rhubarb collected by Risø at Vaag-Lobra road in July 1987

^{90}Sr Bq kg^{-1}	0.35
^{90}Sr Bq $(kg\ Ca)^{-1}$	1126
^{137}Cs Bq kg^{-1}	0.154 A
^{137}Cs Bq $(kg\ K)^{-1}$	54 A
$^{134}Cs/^{137}Cs$	-

2.2.7.5. Faroese Bread

Rye bread and white bread were collected at Thorshavn in June. The levels in white bread were 0.113 Bq ^{90}Sr kg^{-1} and 0.61 Bq ^{137}Cs kg^{-1}. The rye bread collected in 1987 contained 0.18 Bq ^{90}Sr kg^{-1} and 6.0 Bq ^{137}Cs kg^{-1}. The bread ^{137}Cs levels were 10 to 30 times higher than in 1986. All of the radiocesium in bread apparently originated from Chernobyl.

Table 2.2.7.5. Strontium-90 and radiocesium in Faroese bread in June 1987

Sort	Bq ^{90}Sr kg^{-1}	Bq ^{90}Sr (kg Ca)$^{-1}$	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs (kg K)$^{-1}$	$\frac{^{134}Cs}{^{137}Cs}$
White bread	0.113	58	0.61	440	0.47
Rye bread	0.180	172	6.0	2900	0.40

2.2.7.6. Faroese Eggs

Eggs were collected from Thorshavn in 1987. The levels of hens eggs were 0.038 Bq ^{90}Sr kg^{-1} (56 Bq (kg Ca)$^{-1}$ and 1.05 Bq ^{137}Cs kg^{-1} (680 Bq ^{137}Cs (kg K)$^{-1}$). About 90% of the ^{137}Cs was from Chernobyl.

Table 2.2.7.6. Strontium-90 and radiocesium in Faroese eggs collected in 1987

Date	Bq ^{90}Sr kg^{-1}	Bq ^{90}Sr (kg Ca)$^{-1}$	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs (kg K)$^{-1}$	$\frac{^{134}Cs}{^{137}Cs}$
June	0.032	53	0.53	460	0.34
28/2 + 6/6 + 15/6	0.044	59	1.57	890	0.31

2.2.8. Humans from the Faroes

2.2.8.1. Strontium-90 in Human Bone

In 1987 six human bone samples were obtained from Dronning Alexandrine's Hospital in Thorshavn. Table 2.2.8.1 shows the result. The mean concentration was 37 Bq ^{90}Sr (kg Ca)$^{-1}$. In Denmark [3)] we found 20 in this age group in 1987.

Table 2.2.8.1. Strontium-90 in human bone collected in the Faroes in 1987

Age in years	Month of death	Sex	Bq ^{90}Sr (kg Ca)$^{-1}$
71	Jan	F	55
57	Feb	F	24
89	Mar	F	46
83	Apr	F	41
93	Apr	F	25
79	Aug	F	33

2.2.9. Fodder from the Faroes

Various Faroese samples of fodder were collected by Risø in July 1987 (cf. Table 2.2.9). The samples of hay may be compared with those of grass from Thorshavn (cf. Tables 2.2.2.1 and 2.2.2.2). The 1987 hay contained 5800 Bq ^{137}Cs (kg K)$^{-1}$, which is 36% of the grass level in Table 2.2.2.2 but five times the concentrations in Table 2.2.2.1. The 1986 hay level was twice the grass level in 1986 (cf. Risø-R-550, Table 2.2.2.1)[4)]. The conclusion is that it seems difficult to obtain representative grass and hay samples from a given location in the Faroes, due to large inhomogeneities in the activity content of grass. The silage and hay samples from 1986 show that 71% of the ^{137}Cs in these samples came from Chernobyl. In the hay from 1987, 88% of the ^{137}Cs came from Chernobyl.

Table 2.2.9. Radiocesium in fodder collected in the Faroes by Risø in July 1987

Species	Location	Date	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs $(kg\ K)^{-1}$	$\frac{^{134}Cs}{^{137}Cs}$
Silage	Sund/Strømø	24 Aug 1986	46	42000	0.39
Concentrates	Klaksvig	July 1987	2.8	270	0.32
Concentrates with fish	Sund/Strømø	July 1987	2.6	250	-
Hay	Sund/Strømø	July 1986	290	26000	0.33
Hay	Sund/Strømø	July 1987	66	5800	-

2.2.10. Moss and Lichen from the Faroes

Apparently all radiocesium in the moss and lichen samples shown in Table 2.2.10 came from Chernobyl. The very low $^{90}Sr/^{137}Cs$ ratios: 0.017 and 0.005, respectively, suggest that also the ^{90}Sr was Chernobyl derived. The ^{137}Cs deposit in moss (1590 Bq m^{-2}) was close to the measured fallout from Chernobyl in 1986 (1700 Bq ^{137}Cs m^{-2})[4].

Table 2.2.10. Radionuclides in moss and lichen collected at Thorshavn in the Faroes by Risø in July 1987

Species	Unit	^{90}Sr	^{106}Ru	^{134}Cs	^{137}Cs	^{40}K*	$\frac{^{134}Cs}{^{137}Cs}$
Moss	Bq kg^{-1} dry	10.1	67	220	600	1.57	0.37
Moss	Bq m^{-2}	27	178	580	1590	-	
Lichen	Bq kg^{-1} dry	4.5	-	340	850	1.43 A	0.40
Lichen	Bq m^{-2}	1.15	-	86	220	-	

*Unit: g kg^{-1} dry.

2.3. Estimate of the Mean Contents of ^{90}Sr and ^{137}Cs in the Faroese Human Diet in 1987

2.3.1. Annual Quantities

The annual quantities are still based on the estimate made by the late Professor E. Hoff-Jørgensen in 1962[1] assuming a daily pro capite intake of approximately 3000 calories (12.6 MJ).

2.3.2. Milk and Cream

75% of the milk consumed in the Faroes is of local origin, and the remainder comes from Denmark. Hence the ^{90}Sr content in milk consumed in the Faroes in 1987 was $1.2 \times (0.75 \times 0.064 + 0.25 \times 0.059) = 0.075$ Bq ^{90}Sr kg^{-1}, and the ^{137}Cs content was $0.75 \times 7.6 + 0.25 \times 0.60 = 5.85$ Bq ^{137}Cs kg^{-1} (cf. 2.2.3 and Ref. 3). 1 kg milk contains 1.2 g Ca.

2.3.3. Cheese

Nearly all cheese consumed in the Faroes is of Danish origin, and the Danish figures from ref. 3 were used: 0.50 Bq ^{90}Sr kg^{-1} and 0.43 Bq ^{137}Cs kg^{-1}.

2.3.4. Grain Products

As most grain products are imported from Denmark, the Danish figures for 1987[3)] were used in the calculation of the Faroese levels. The mean daily consumption of grain products in the Faroes is, as in Denmark, 80 g rye flour, 120 g wheat flour, and 20 g grits. Hence the mean concentration of ^{90}Sr in grain products consumed in the Faroes in 1987 is 0.23 Bq ^{90}Sr kg^{-1} and 3.2 Bq ^{137}Cs kg^{-1}.

2.3.5. Potatoes

All potatoes consumed in the Faroes are assumed to be of local origin. The values from 2.2.7.4 were used, i.e. 0.059 Bq ^{90}Sr kg^{-1} and 3.6 Bq ^{137}Cs kg^{-1}.

2.3.6. Other Vegetables and Fruit

As the amount of vegetables and fruit grown in the Faroes is limited, the Danish figures from 1987[3)] were used. Thus the mean content in vegetables other than potatoes was 0.32 Bq ^{90}Sr kg^{-1} and 0.064 Bq ^{137}Cs kg^{-1}. The mean content in fruit was 0.065 Bq ^{90}Sr kg^{-1} and 0.16 Bq ^{137}Cs kg^{-1}.

2.3.7. Meat and Eggs

Meat and egg consumption in the Faroes is estimated to consist of 50% locally produced mutton (or lamb), 25% local whale meat, and 25% sea birds and eggs.

For lamb we use the mean of the samples obtained in 1987, i.e. 0.22 Bq ^{90}Sr kg^{-1} and 107 Bq ^{137}Cs kg^{-1}. Whale meat contained 0 Bq ^{90}Sr kg^{-1} and 0.80 Bq ^{137}Cs kg^{-1}, sea birds contained 0 Bq ^{90}Sr kg^{-1} and 0.15 Bq ^{137}Cs kg^{-1}, and eggs (cf. 2.2.4 and 2.2.7.6): 0.038 Bq ^{90}Sr kg^{-1} and 1.05 Bq ^{137}Cs kg^{-1}. Hence we estimate the mean content of ^{90}Sr in meat and eggs consumed in 1987 to be $0.50 \times 0.22 + 0.25 \times 0 + 0.25 \times (0 + 0.038)/2 = 0.115$ Bq ^{90}Sr kg^{-1} and the ^{137}Cs content to be $0.50 \times 107 + 0.25 \times 0.80 + 0.25 \times (0.15 + 1.05)/2 =$ 53.8 Bq ^{137}Cs kg^{-1}.

2.3.8. Fish

All fish consumed in the Faroes is of local origin, and the mean content in fish, obtained from subsection 2.2.5, was 0.00077 Bq ^{90}Sr kg^{-1} and 0.63 Bq ^{137}Cs kg^{-1}.

2.3.9. Coffee and Tea

The Danish figures for 1987[3)] were used, i.e. 0.41 Bq ^{90}Sr kg^{-1} and 1.29 Bq ^{137}Cs kg^{-1}.

2.3.10. Drinking Water

The mean value found in Table 2.2.6.1 was used, i.e. 0.0023 Bq ^{90}Sr kg^{-1}. The ^{137}Cs content was estimated from a drinking water sampling in July 1987; the mean value was 0.007 Bq ^{137}Cs l^{-1}.

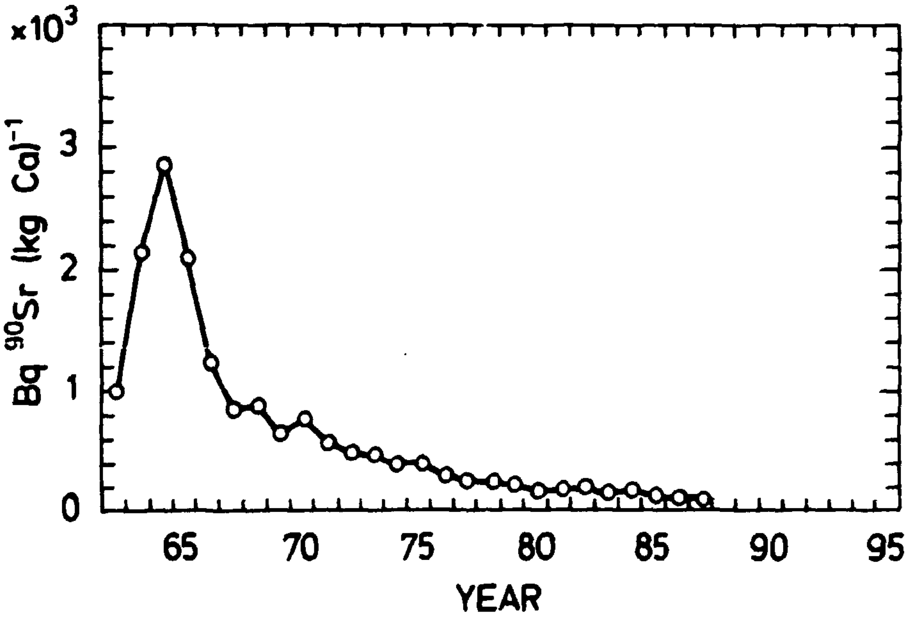
Tables 2.3.1 and 2.3.2 show the diet estimates of ^{90}Sr and ^{137}Cs, respectively.

Table 2.3.1. Estimate of the mean content of ^{90}Sr in the human diet in the Faroe Islands in 1987

Type of food	Annual quantity in kg	Bq ^{90}Sr per kg	Total Bq ^{90}Sr	Percentage of total Bq ^{90}Sr in food
Milk and cream	146	0.075	10.95	20.1
Cheese	7.3	0.50	3.65	6.7
Grain products	80	0.23	18.40	33.7
Potatoes	91	0.059	5.37	9.9
Vegetables	20	0.32	6.40	11.7
Fruit	18	0.065	1.17	2.2
Meat and eggs	37	0.115	4.26	7.8
Fish	91	0.00077	0.07	0.1
Coffee and tea	7.3	0.41	2.99	5.5
Drinking water	548	0.0023	1.26	2.3
Total			54.52	

The mean annual calcium intake is estimated to be 0.6 kg (approx. 200-250 g of creta praeparata). Hence the ratio: Bq ^{90}Sr (kg Ca)$^{-1}$ in total Faroese diet was 91 (2.5 pCi ^{90}Sr (g Ca)$^{-1}$).

Fig. 2.3.1. Strontium-90 in Faroese diet, 1962-1987.



2.3.11. Discussion

Figures 2.3.1 and 2.3.2 show the Faroese diet levels since 1962.

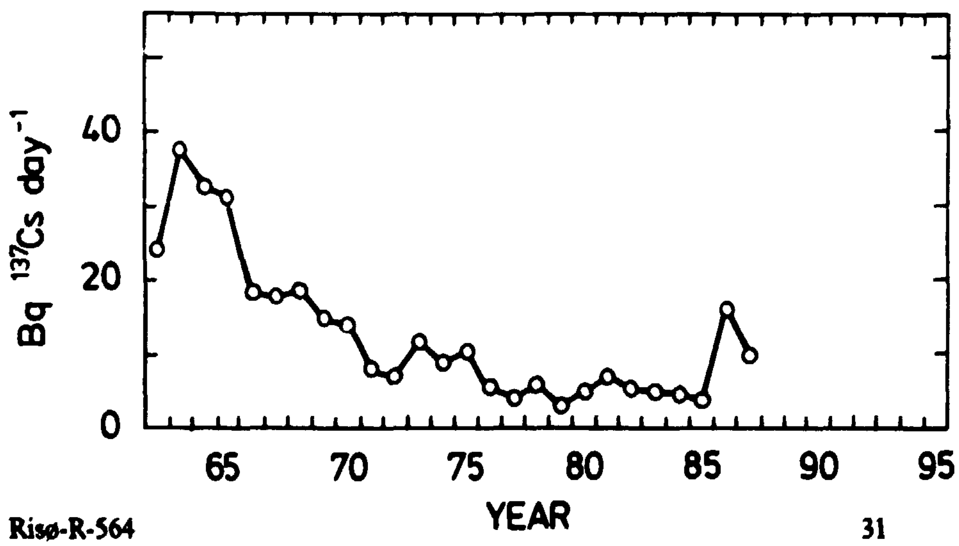
The 1987 ^{90}Sr level in the total Faroese diet was equal to the 1986 concentration. The ^{137}Cs level was 80% of the 1986 level. A total diet sample was collected in Thorshavn by Risø in July 1987. The composition of the sample was that given in Tables 2.3.1 and 2.3.2. The sample contained 91.5 Bq ^{90}Sr (kg Ca)$^{-1}$ corresponding to a daily intake of 0.109 Bq ^{90}Sr and 1.19 g Ca. Compared with Table 2.3.1, the $^{90}Sr/Ca$ level was in excellent agreement, but the daily intakes of ^{90}Sr and Ca were both 1.37 times lower than estimated in the table.

Table 2.3.2. Estimate of the mean content of ^{137}Cs in the human diet in the Faroe Islands in 1987

Type of food	Annual quantity in kg	Bq ^{137}Cs per kg	Total Bq ^{137}Cs	Percentage of total Bq ^{137}Cs in food
Milk and cream	146	5.85	854.1	24.4
Cheese	7.3	0.43	3.14	0.1
Grain products	80	3.2	256.0	7.3
Potatoes	91	3.6	327.6	9.3
Vegetables	20	0.064	1.28	0
Fruit	18	0.16	2.88	0.1
Meat and eggs	37	53.8	1990.6	56.7
Fish	91	0.63	57.3	1.6
Coffee and tea	7.3	1.29	9.4	0.3
Drinking water	548	0.007	5.84	0.2
Total			3508.1	

The mean annual intake of potassium is estimated to be approx. 1.2 kg. Hence the ratio: Bq ^{137}Cs (kg K)$^{-1}$ becomes 2900 (79 pCi ^{137}Cs (g K)$^{-1}$).

Fig. 2.3.2. Cesium-137 in Faroese diet, 1962-1987.



In the case of ^{137}Cs, the Thorshavn diet contained 1800 Bq ^{137}Cs (kg K)$^{-1}$ which was 62% of the estimate in Table 2.3.2. The daily intakes were 6.31 Bq ^{137}Cs, 1.08 Bq ^{134}Cs, and 3.49 g K. The ^{137}Cs level is 66% of that estimated in Table 2.3.2. The potassium intake is in agreement with that in Table 2.3.2. From the ^{134}Cs content in the diet sample, the annual intake of ^{134}Cs with total diet in the Faroes was estimated to be 17% of the ^{137}Cs intake. In 1986 it was 39%. In general, the total diet sample from Thorshavn seemed to contain less ^{90}Sr and ^{137}Cs than the estimated levels in Tables 2.3.1 and 2.3.2; this is probably because important components of the Thorshavn diet (milk, potatoes and lamb) are generally lower in radioactivity content than the Faroese average.

The main contributors to the ^{90}Sr content in the Faroese diet were milk products, cereals and potatoes, which together accounted for approximately 70% of the total ^{90}Sr content in the diet in 1987. As regards ^{137}Cs, potatoes, milk products, and meat (lamb) were the most important contributors. In 1987, 91% of the total ^{137}Cs content in the diet originated from these products.

The Faroese mean diet contained 0.93 times as much ^{90}Sr and approximately 6 times as much ^{137}Cs as the Danish diet in 1987[3].

The difference between the ^{137}Cs present in the Faroese and Danish diets became a little less after the Chernobyl accident, because increased in importance of direct deposition. This did not differ so much between the Faroes and Denmark as did indirect contamination, however.

2.4. Conclusion

2.4.1.

The ^{90}Sr fallout rate in the Faroes in 1987 was approximately 1.1 Bq ^{90}Sr m^{-2}. The accumulated fallout by the end of 1987 was estimated to be approximately 3250 Bq ^{90}Sr m^{-2} (90 mCi km^{-2}) (the mean at Thorshavn and Klaksvig).

The ^{137}Cs mean deposit was 105 Bq m^{-2} in 1987, i.e. 5% of the original deposit from the Chernobyl accident.

2.4.2.

The mean level of ^{90}Sr in Faroese milk was 64 Bq (kg Ca)$^{-1}$. The ^{137}Cs concentration was 7600 Bq ^{137}Cs m^{-3}.

Lamb contained 107 Bq ^{137}Cs kg^{-1} in 1987. Fish showed a mean level of 0.63 Bq ^{137}Cs kg^{-1}.

The mean content of ^{90}Sr in drinking water was 2.3 Bq m^{-3}.

The mean daily pro capite intakes resulting from the Faroese diet in 1987 were estimated to be 0.15 Bq ^{90}Sr and 9.6 Bq ^{137}Cs.

2.4.3.

The mean content of ^{137}Cs in the Faroese adult was estimated to be approximately 8700 Bq ^{137}Cs (kg K)$^{-1}$. This estimate is based on the diet estimate.

2.4.4.

In terrestrial samples (grass, milk, lamb, drinking water, potatoes, eggs, and fodder) collected in the Faroes in 1987, 75-80% of the ^{137}Cs came from Chernobyl. In marine fish about two-thirds of the ^{137}Cs was from the Chernobyl accident.

Appendix 2A

Predictions and Observations of ^{90}Sr and ^{137}Cs in Faroese Samples in 1987

The models used for the predictions shown in Table 2A were based on data collected 1962-1976[5]. We observe that nearly all models overestimated the levels in 1987, except those for ^{137}Cs in cod fish and in lamb. The mean levels for these two sample types were, however, encumbered with large standard errors.

Table 2A. Comparison between observed and predicted ^{90}Sr and ^{137}Cs concentrations in Faroese samples collected in 1987

Sample	Unit	Observed ±1 S.E.		Number of samples	Predicted	Obs./pre. ±1 S.E.	Model in ref. 5
Drinking water, Thorshavn	Bq ^{90}Sr m^{-3}	3.8	±0.6	2	9.4	0.40±0.06	C.1.4.1 No. 9
Drinking water, Klaksvig	Bq ^{90}Sr m^{-3}	0.83	±0.02	2	1.77	0.47±0.01	C.1.4.1 No. 10
Drinking water, Tværå	Bq ^{90}Sr m^{-3}	2.4	±0.2	2	2.4	1.00±0.08	C.1.4.1 No. 11
Sea water	Bq ^{90}Sr m^{-3}	1.73	±0.12	3	1.90	0.91±0.06	C.1.5.1 No. 3
Sea water	Bq ^{137}Cs m^{-3}	3.5	±0.2	3	9.9	0.35±0.02	C.1.5.1 No. 3(×1.6)
Grass	Bq ^{90}Sr (kg Ca)$^{-1}$	2300	±640	6	4800	0.48±0.13	C.2.4.1 No. 4
Grass	Bq ^{137}Cs (kg K)$^{-1}$	8300	±2700	6	24000	0.35±0.11	C.2.4.2 No. 3
Potatoes	Bq ^{90}Sr kg^{-1}	0.069	±0.017	3	0.21	0.33±0.08	C.2.5.1 No. 11
Potatoes	Bq ^{137}Cs kg^{-1}	4.6	±3.4	3	6.8	0.68±0.50	C.2.5.3 No. 8
*Milk	Bq ^{90}Sr (kg Ca)$^{-1}$	59	±2	12	300	0.20±0.01	C.3.3.1 No. 1
*Milk Thorshavn	Bq ^{137}Cs (kg K)$^{-1}$	2300	±300	12	6400	0.36±0.05	C.3.3.2 No. 1
*Milk Klaksvik	Bq ^{137}Cs (kg K)$^{-1}$	2200	±210	12	10600	0.21±0.02	C.3.3.2 No. 3
*Milk Tværå	Bq ^{137}Cs (kg K)$^{-1}$	5500	±570	12	12200	0.45±0.05	C.3.3.2 No. 5
Cod fish	Bq ^{90}Sr (kg Ca)$^{-1}$	8.5	±3.7	2	18.3	0.46±0.20	C.3.5.1 No. 3
Cod fish	Bq ^{137}Cs kg^{-1}	0.70	±0.17	4	0.23	3.04±0.74	C.3.5.2 No. 2
Lamb meat	Bq ^{90}Sr (kg Ca)$^{-1}$	1480	±630	3	1060	1.40±0.59	C.3.4.1 No. 5
Lamb meat	Bq ^{137}Cs (kg K)$^{-1}$	40000	±14500	3	6700	6.0 ±2.2	C.3.4.2 No. 5
Lamb bone	Bq ^{90}Sr (kg Ca)$^{-1}$	1020	±280	6	1950	0.52±0.14	C.3.4.3 No. 1

*"Milk year": June 1987 - May 1988.

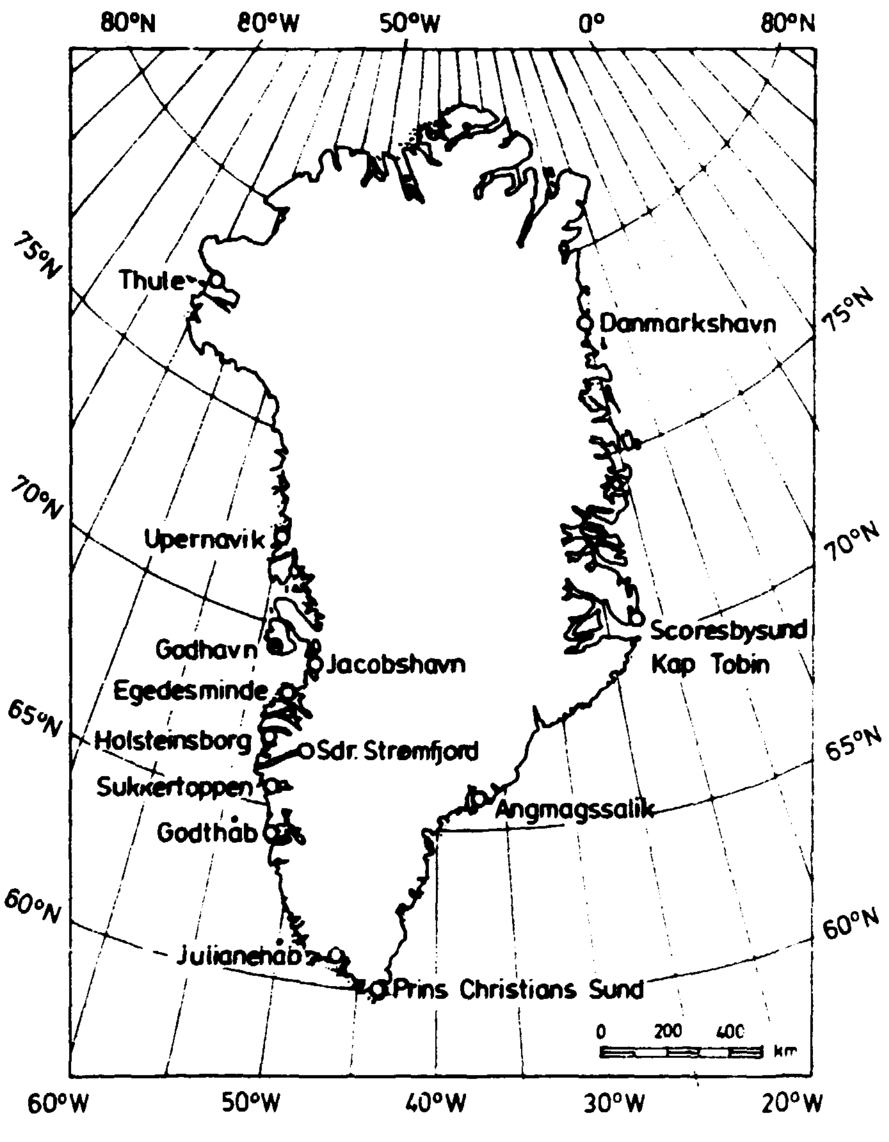
3. Environmental Radioactivity in Greenland in 1987

3.1. Introduction

3.1.1.

In 1987 the sampling programme was similar to that used in previous years, but the Chernobyl accident caused certain modifications in order to estimate the deposition of radiocesium.

Fig. 3.1. Greenland



3.1.2.

As hitherto, samples were collected through the local district physicians and the head of the telestations. However, we have also obtained samples collected by the Greenland Fisheries and Environmental Research Institute. A number of the Greenland food samples were obtained from K.N.I. (Kalaallit Niuerfiat) (Greenland Trade).

3.1.3.

The estimated mean diet in Grenland was the same as that in 1962, i.e., it agreed with the estimate given by the late Professor E. Hoff-Jørgensen.

3.1.4.

The environmental studies in Greenland were carried out together with corresponding investigations in Denmark (cf. Risø Report No. 563[3]) and in the Faroes (cf. Chapter 2 in this report).

3.1.5.

The present report does not repeat information concerning sample collection and analysis already given in ref. 2.

3.2. Results and discussion

3.2.1.1. Strontium-90 in Greenland Precipitation.

Table 3.2.1.1 shows the results of the measurements.

The ^{90}Sr fallout in 1987 at the Greenland stations were generally lower as compared with 1986.

Figure 3.2.1 shows the accumulated ^{90}Sr at the various stations in Greenland since measurements began in 1962.

Table 3.2.1.1.1. Strontium-90 in precipitation in Greenland in 1987. (Sampling area: 0.02 m²)

Location m precipitation	Unit	Jan-March	April-June	July-Sept	Oct-Dec	1987
Godthåb	Bq m^{-3}	3.2		0.09 B	1.74	1.94
Σ 0.612	Bq m^{-2}	0.79		0.01 B	0.38	1.19
Scoresbysund	Bq m^{-3}	0.3 B	1.05 A	0.6 B	0.09 B	0.42
Σ 0.532	Bq m^{-2}	0.06 B	0.110 A	0.05 B	0.01 B	0.23
Danmarkshavn	Bq m^{-3}	4.7	3	29 A	5 B	5.9
Σ 0.095	Bq m^{-2}	0.21	0.09 B	0.20 A	0.06 B	0.56
Prins Chr.Sund	Bq m^{-3}		B.D.L.	0.83 A	0.35 B	(0.61)
Σ (1.360)	Bq m^{-2}		B.D.L.	0.40 A	0.14 B	(0.54)

Table 3.2.1.1.2. Fallout rates and accumulated fallout (Bq m^{-2}) in Greenland 1950-1987

	Scoresbysund (Kap Tobin)		Pr.Chr.Sund		Godthåb		Upernavik	
	d_i	$A_{i(29)}$	d_i	$A_{i(29)}$	d_i	$A_{i(29)}$	d_i	$A_{i(29)}$
1950	0.37	0.36	2.04	1.99	0.57	0.56	0.20	0.20
1951	1.76	2.06	9.79	11.50	2.77	3.25	0.97	1.14
1952	3.44	5.38	19.19	29.97	5.42	8.46	1.90	2.97
1953	8.70	13.74	48.47	76.59	13.69	21.63	4.81	7.60
1954	33.06	45.69	184.28	254.71	52.05	71.94	18.29	25.28
1955	43.49	87.08	242.45	485.41	68.48	137.10	24.06	48.17
1956	53.93	137.67	300.61	767.46	84.91	216.76	29.83	76.16
1957	53.93	187.08	300.61	1042.85	84.91	294.54	29.83	103.49
1958	74.81	255.70	417.04	1425.40	117.79	402.59	41.39	141.45
1959	106.11	353.27	591.53	1969.29	167.07	556.21	58.70	195.43
1960	19.82	364.28	110.51	2030.68	31.21	573.55	10.97	201.52
1961	25.75	380.83	143.57	2122.90	40.55	599.60	14.25	210.67
1962	129.17	497.95	720.07	2775.83	203.38	784.01	71.46	275.46
1963	290.45	769.78	1545.12	4218.89	475.45	1229.72	160.58	425.75
1964	180.93	928.26	929.07	5026.38	258.63	1453.19	100.27	513.59
1965	68.82	973.53	383.32	5281.93	166.50	1581.44	38.11	538.67
1966	37.37	987.02	207.94	5360.21	43.29	1586.36	20.72	546.18
1967	18.13	981.41	73.63	5305.51	32.56	1580.68	12.21	545.20
1968	24.42	982.08	136.16	5313.15	[illegible]00	1579.48	13.32	545.33
1969	18.13	976.59	72.89	5258.83	22.20	1563.85	6.73	539.03
1970	33.30	986.03	59.20	5192.43	34.41	1560.51	12.58	538.58
1971	15.17	977.56	122.84	5189.73	32.56	1555.44	8.14	533.81
1972	12.58	966.75	55.50	5121.35	15.17	1533.52	4.07	525.17
1973	3.40	947.24	17.91	5017.88	6.92	1504.06	2.78	515.48
1974	12.21	936.79	45.88	4944.16	18.83	1486.92	13.14	516.13
1975	4.48	919.04	86.21	4911.57	19.57	1470.91	8.44	512.18
1976	3.00	900.26	11.17	4806.47	4.85	1440.91	2.44	502.46
1977	5.18	884.06	34.78	4726.91	14.06	1420.60	7.03	497.46
1978	10.36	873.29	54.39	4668.38	14.43	1401.14	7.77	493.30
1979	2.81	855.41	10.36	4568.24	9.99	1377.80	3.70	485.26
1980	2.57	837.72	5.74	4465.95	3.87	1349.04	3.02	476.75
1981	4.50	822.33	27.79	4387.60	10.57	1327.50	4.53	469.91
1982	1.97	804.83	5.19	4289.05	2.15	1298.24	1.27	460.05
1983	1.18	786.97	(10.1)	4197.63	2.98	1270.49	1.53	450.68
1984	0.87	769.23	(1.65)	4100.10	1.62	1242.06	1.79	441.78
1985	1.36	752.39	(1.6)	4004.82	(1.7)	1214.38	(~0.3)	431.64
1986	1.14	735.76	~1.5	3911.73	1.64	1187.34	~0.3	421.75
1987	0.23	718.61	~1	3820.32	1.10	1160.46	(~0.2)	411.98

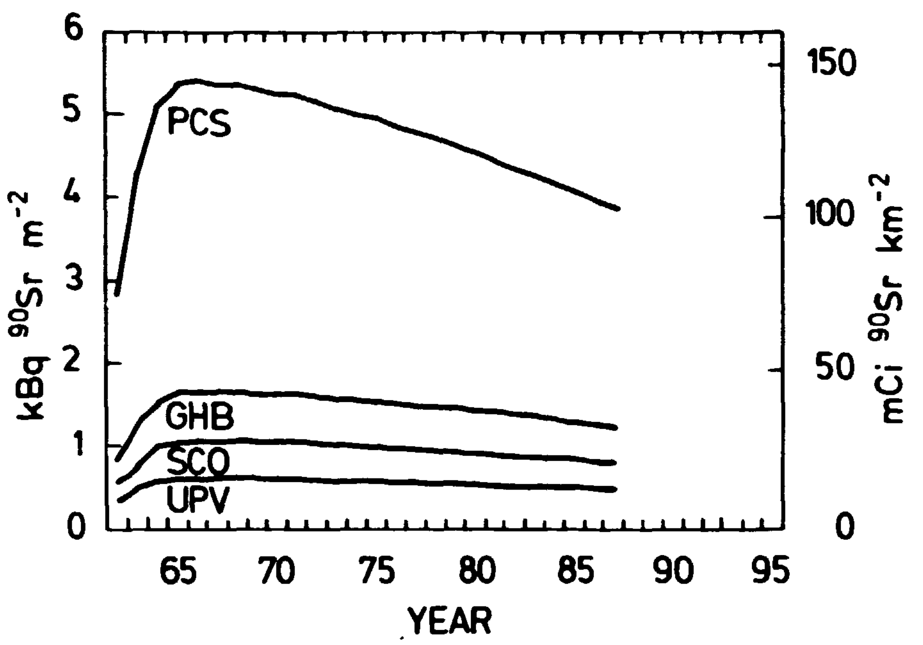


Fig. 3.2.1. Accumulated ^{90}Sr at Prins Chr. Sund, Godthåb, Scoresbysund (Kap Tobin) and Upernavik calculated from precipitation measurements since 1962. The accumulated fallout by 1962 was estimated from the Danish data (cf. Risø Report No. 509[3]), Appendix D) and from the ratio of the ^{90}Sr fallout at the Greenland stations to that in Denmark in the period 1962-1987.

3.2.1.2. Radiocesium in Greenland Precipitation and Soil.

After the Chernobyl accident the rain water samples used for ^{90}Sr analysis were also analysed for ^{137}Cs and ^{134}Cs (Table 3.2.1.2.1). Chernobyl debris was present in the precipitation collected at Godthåb and Scoresbysund. As ex-

Table 3.2.1.2.1. Cesium-137 in precipitation in Greenland in 1987.

Location	Unit	Jan-March	April-June	July-Sept	Oct-Dec	1987
Godthåb	Bq m^{-3}	9.2 A		B.D.L.	B.D.L.	~3*
	Bq m^{-2}	1.63 A		B.D.L.	B.D.L.	
Scoresbysund	Bq m^{-3}	10.2 A	23	B.D.L.	B.D.L.	~7*
	Bq m^{-2}	2.4 A	2.4	B.D.L.	B.D.L.	
Danmarkshavn	Bq m^{-3}					B.D.L.
	Bq m^{-2}					B.D.L.
Prins Chr.Sund	Bq m^{-3}		B.D.L.	2.2 B	B.D.L.	
	Bq m^{-2}		B.D.L.	1.0 B	B.D.L.	

*Based upon measurements of combined samples for the whole year and assuming a chemical yield of the $PtCl_6^{--}$ precipitation of the AMP of 60%, which has been found for Faroese drinking water samples.

pected, the levels were higher on the east than on the west coast of Greenland. The ^{137}Cs fallout in 1987 at Godthåb and Scoresbysund was about 3% of the original deposition from Chernobyl. This resuspension corresponded to that observed in Denmark in 1987[3].

A sample of soil was obtained from Godthåb collected October 1987. The contribution of Chernobyl ^{137}Cs in this sample was 83 Bq m^{-2}. Total ^{137}Cs was 440 Bq m^{-2}.

3.2.2. Radionuclides in Greenland Sea Water

Table 3.2.2 shows the samplings carried out in 1987.

Table 3.2.2. Radionuclides in surface sea water collected in Greenland in the autumn of 1987

Location	Bq ^{137}Cs m^{-3}	Bq ^{90}Sr m^{-3}	Salinity ‰
Danmarkshavn	6.0	3.6	22.3
Godthåb	5.1	2.1	31.8
Prins Chr. Sund	6.4	2.6	29.4

3.2.3. Strontium-90 and Radiocesium in Greenland Terrestrial Mammals

Reindeer samples all contained Chernobyl radiocesium in 1987 (Table 3.2.3.1). Approximately 20% of the ^{137}Cs came from Chernobyl.

The mean content in the reindeer samples was 50 Bq ^{137}Cs kg^{-1} meat. ^{90}Sr was 0.16 Bq kg^{-1} meat and 2700 Bq (kg Ca)$^{-1}$ in bone.

A ptarmigan from Holsteinsborg contained 0.58 Bq ^{137}Cs kg^{-1}, 0.20 Bq ^{90}Sr kg^{-1} and the bone contained 2300 Bq ^{90}Sr (kg Ca)$^{-1}$.

Table 3.2.3.1. Radiocesium and strontium-90 in Greenland reindeer collected in 1987

Location	Month	Sample	Bq ^{137}Cs kg^{-1} meat	$\frac{^{134}Cs}{^{137}Cs}$	Bq ^{90}Sr kg^{-1} meat	Bq ^{90}Sr (kg Ca)$^{-1}$ in bone	g K kg^{-1} meat	g Ca kg^{-1} meat
Godthåb	Feb	I	70	0.087		4400	3.0	
-"-	"	II	68	0.088		4600	3.2	
-"-	"	III	52	0.092	0.21	2500	2.4	0.101
-"-	"	IV	70	0.084		4100	3.3	
-"-	"	V	67	0.087		4400	2.9	
* -"-	Aug-Sept		15.8	0.081		2300	3.2	
*Holsteinsborg	-"-	I	34	-	0.20	420	2.7	0.42
* -"-	-"-	II	39	-	0.152	510	3.0	0.28
*KNI					0.24			0.154
KNI	June	I	41	0.058	0.057	1850	3.9	0.035
-"-	"	II	42	0.059	0.117	2200	3.5	0.060

* Wild reindeer.

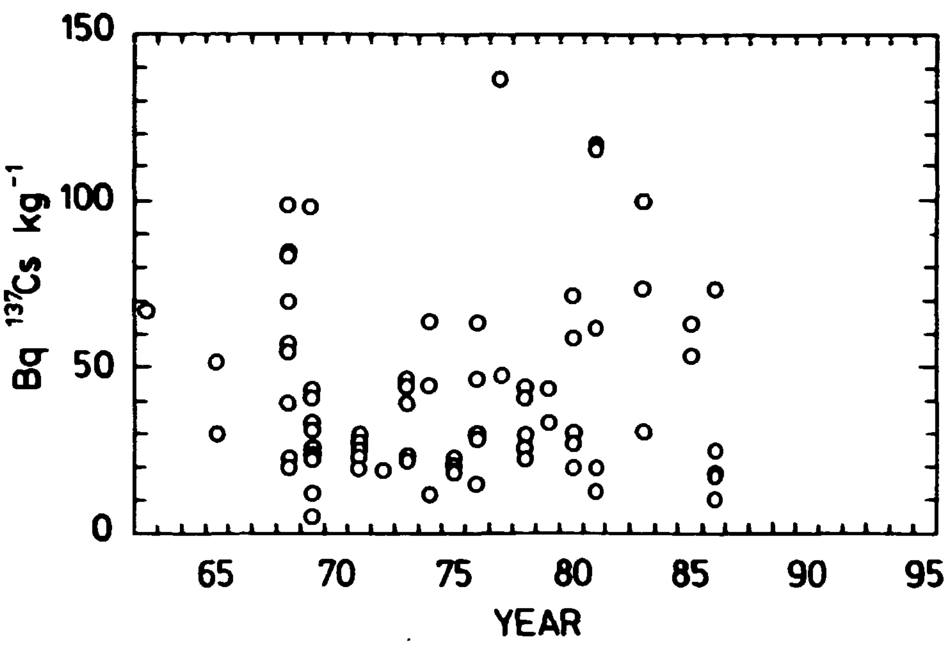


Fig.3.2.3. Cesium-137 in Greenland mutton, 1962-1987.

3.2.4. Strontium-90 and Radiocesium in Greenland Aquatic Animals

Four of the aquatic animal samples (Table 3.2.4 1) contained Chernobyl ^{137}Cs: a whale from Holsteinsborg (11% Chernobyl ^{137}Cs), salmons from Holsteinsborg and Godthåb (43%, 18% and 22%, respectively).

The mean concentrations in seals were 0.16 Bq ^{137}Cs kg^{-1} and 0.002 Bq ^{90}Sr kg^{-1}. Whales contained 0.54 Bq ^{137}Cs kg^{-1} and 0.001 Bq ^{90}Sr kg^{-1}. Fish contained 0.55 Bq ^{137}Cs kg^{-1} and 0.13 Bq ^{90}Sr kg^{-1}, and shrimps contained 0.131 Bq ^{137}Cs kg^{-1} and 0.027 Bq ^{90}Sr kg^{-1}.

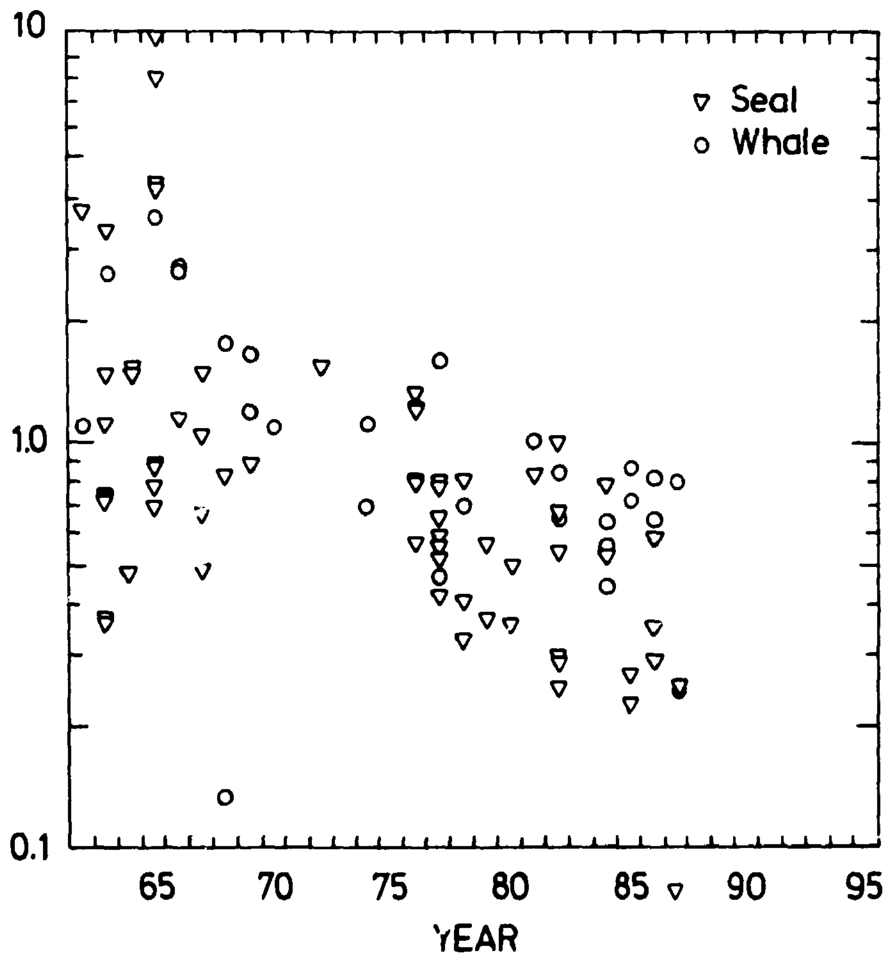
Table 3.2.4.1. Radiocesium in aquatic animals from Greenland in 1987

Species	Location	Month	^{137}Cs Bq kg^{-1}	$\frac{^{134}Cs}{^{137}Cs}$	g K kg^{-1}
Seal	Egedesminde	Feb	0.25	-	1.46
"	Godthåb	July	0.078	-	1.32
Whale	Egedesminde	March	0.27	-	2.62
Piked whale	Holsteinsborg	July-Aug	0.81	0.041	2.75
Salmon	Holsteinsborg	July	0.31	0.16 A	3.38
Salmon I	Godthåb	July	0.80	0.068 A	3.17
Salmon II	Godthåb	July	0.53	0.081 A	3.55
Shrimps	KNI		0.131	-	1.37

Table 3.2.4.2. Strontium-90 in aquatic animals from Greenland in 1987

Species	Location	Month	^{90}Sr Bq kg^{-1} flesh	^{90}Sr Bq $(kg\ Ca)^{-1}$ bone	g Ca kg^{-1} flesh
Seal	Egedesminde	Feb	0.0017 B	0.81 B	0.077
"	Godthåb	July	0.0020 B	1.70	0.048
Whale	Egedesminde	March	0.0008 B		0.39
Piked whale	Holsteinsborg	July-Aug	0.0010 B		0.0035
Salmon	Holsteinsborg	July	0.0007 B	2.7	0.21
Salmon I	Godthåb	July	0.29		0.195
Salmon II	Godthåb	July	0.103		0.23
Shrimps	KNI		0.027		0.42

Fig. 3.2.4. Cesium-137 in seal and whale meat from Greenland 1962-1987.



3.2.5. Radionuclides in Greenland Vegetation

Chernobyl ^{137}Cs was present in moss, lichen, and grass from Greenland in 1987. Moss and lichen contained about 5% and grass twice as much from Chernobyl. The deposition of Chernobyl ^{137}Cs at Egedesminde was estimated from the two moss samples to be 16 Bq ^{137}Cs m^{-2}. The lichen samples from Jacobshavn and Godthåb suggested Chernobyl depositions of 9 and 51 Bq ^{137}Cs m^{-2}, respectively. These estimates are one-third to one-half of those obtained from soil measurements in 1986[4].

Table 3.2.5.1 shows that ^{99}Tc was measurable in seaweed from Godthåb. Ascophyllum contained two times higher levels than Fucus, which is in agreement with earlier observations (cf. Risø-R 510)[4].

The transfer factor from Sellafield to W-Greenland waters has been determined to be 0.4 Bq per PBq y^{-1} [9] or in fucus 40 mBq kg^{-1} d.w. per TBq y^{-1}. Hence the expected discharge observed should have been 150 TBq y^{-1}. This is close to the discharge in 1978 (179 TBq). The transit time from Sellafield to W-Greenland should then have been 9 years, which seems reasonable.

Table 3.2.5.1. Radionuclides in seaweed collected at Godthåb in 1987

Species	Date	^{90}Sr Bq kg^{-1} dry	^{90}Sr Bq $(kg\ Ca)^{-1}$	^{99}Tc Bq kg^{-1} dry	^{137}Cs Bq kg^{-1} dry	g K kg^{-1} dry	g Ca kg^{-1} dry
Fucus vesiculosus	8/8	0.24 A	19.9 A	5.9	0.48	20.8	11.9
Ascophyllum nodosum	10/9	-	13.8	12.0	0.34	17.3	-

Table 3.2.5.2. Radionuclides in lichen, moss, and grass collected in Greenland in 1987

Species	Location	Month	^{90}Sr Bq kg^{-1} dry	^{90}Sr Bq m^{-2}	^{134}Cs Bq kg^{-1} dry	^{134}Cs Bq m^{-2}	^{137}Cs Bq kg^{-1} dry	^{137}Cs Bq m^{-2}	^{134}Cs / ^{137}Cs
Moss	Egedesminde	July-Aug	43	210	1.89	9.1	102	490	0.0186
Moss	Egedesminde	July-Aug	44	196	0.71	3.1	100	440	0.0071
Moss	Danmarkshavn	Aug	52	167			220	740	
Lichen	Danmarkshavn	Aug	51	84			152	250	
Lichen	Jacobshavn	July	16.6	17.9	3.0	3.2	115	124	0.026
Lichen	Godthåb	Aug	66	210	5.9	18.9	470	1510	0.0126
Grass	Egedesminde	July	6.1		1.45		33		0.044
Grass	Godthåb	Aug	3.1		0.88		27		0.032

3.2.6. Strontium-90, Radiocesium, and Tritium in Greenland Drinking Water

Quarterly samples of drinking water were collected from a number of locations in Greenland. Tables 3.2.6.1-3.2.6.3 show the results from 1987, and Fig. 3.2.6 the geometric annual ^{90}Sr means of all samples for the period 1962-1987.

Table 3.2.6.1. Strontium-90 in drinking water collected in Greenland in 1987 (Unit: Bq m^{-3})

Location	Jan-Mar	April-June	July-Sept	Oct-Dec
Danmarkshavn	22	10.7	4.8	17.7
Scoresbysund	17.2	15.3	12.3	10.6
Prins Chr. Sund		27	6.3	56
Godthåb	8.3	9.6	6.8	
Upernavik		14.3	6.3	

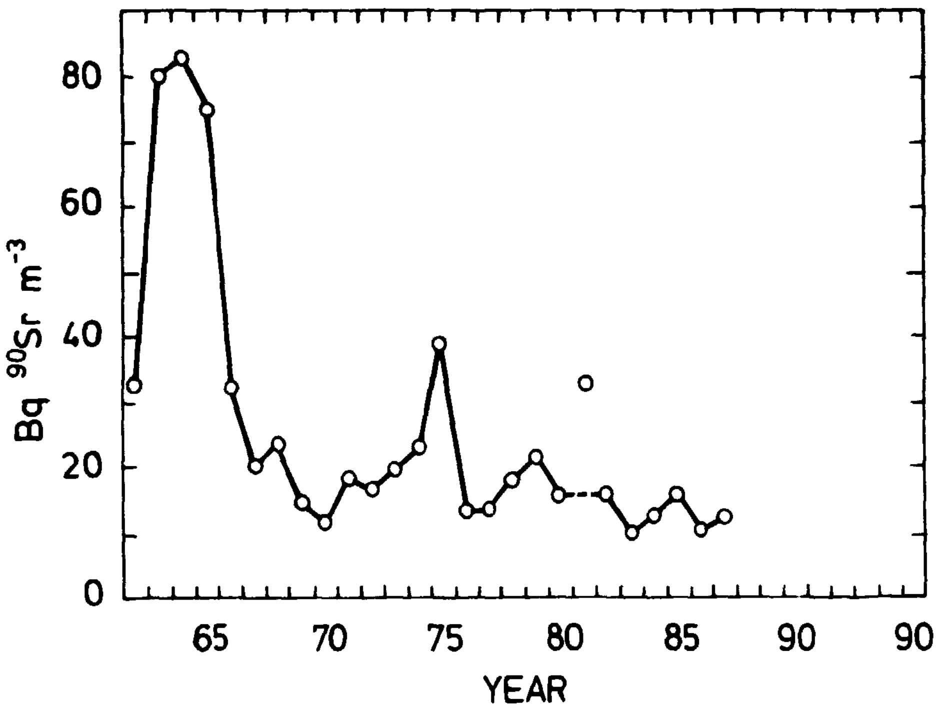


Fig. 3.2.6. Strontium-90 in Greenland drinking water (geometric mean), 1962-1987

Table 3.2.6.2. Cesium-137 in drinking water collected in Greenland in 1987 (Unit: Bq m^{-3})

Location	Jan-Mar	April-June	July-Sept	Oct-Dec
Danmarkshavn	< 2.6	< 4	< 3	< 4
Scoresbysund	1 B	3 B		
Prins Chr. Sund		4.7	< 2.5	3.6 A
Godthåb	3.7	3.2 A	3 B	
Upernavik		3 B	< 3	

Table 3.2.6.3. Tritium in drinking water collected in Greenland in 1987 (Unit: kBq m^{-3})

Location	Jan-March
Danmarkshavn	1.61 ± 0.00
Scoresbysund	B.D.L.
Prins Chr. Sund	B.D.L.
Godthåb	2.04 ± 0.05
Upernavik	2.46 ± 0.10

The error term is 1 S.E. of the mean of double determinations.

As in previous years, we found it most expedient to choose the geometric mean of all figures, i.e. 12.4 Bq ^{90}Sr m^{-3} (0.34 pCi l^{-1}) as representative of the mean level of ^{90}Sr in Greenland drinking water in 1987. This level was in agreement with observations of earlier years (Fig. 3.2.6). The levels in drinking water are still surprisingly high compared with present rain concentrations (cf. Table 3.2.1.1). We have suggested that evaporation from the drinking water reservoirs was responsible for the higher ^{90}Sr levels. Tritium measurements show (Table 3.2.6.2) that Greenland drinking water shows similar tritium levels as rain from Denmark[3)]; hence evaporation seems to be a possible explanation. The high ^{90}Sr levels may, however, also be due to the extraction of old deposited ^{90}Sr activity from the soil by the water collected for drinking. This would also be compatible with "normal" tritium concentrations. If old ice (e.g. from the early sixties) had been the source, we would have expected high tritium concentrations.

3.3. Estimate of the Mean Contents of ^{90}Sr and ^{137}Cs in the Human Diet in Greenland in 1987

3.3.1. The Annual Quantities

The estimate of the daily pro capite intake of the different foods in Greenland is still based on the figures given in 1962 by the late Professor E. Hoff-Jørgensen, in Risø Report No. 65[2)].

3.3.2. Milk Products

All milk consumed in Greenland was imported as milk powder from Denmark. The mean radioactivity content in milk prepared from Danish dried milk produced in 1987 was 0.071 Bq ^{90}Sr kg^{-1} and 0.60 Bq ^{137}Cs kg^{-1} [3)].

Cheese was also imported from Denmark and contained 0.50 Bq ^{90}Sr kg^{-1} and 0.43 Bq ^{137}Cs kg^{-1}.

3.3.3. Grain Products

All grain was imported from Denmark. It is assumed that only grain from the harvest of 1986 was consumed in Greenland during 1987. The daily pro capite consumption was: rye flour (100% extraction): 80 g; wheat flour (75% extraction): 110 g; rye flour (70% extraction): 20 g; biscuits (rye, 100% extraction): 27 g, and grits: 25 g. The content of ^{90}Sr in these five products was 0.43, 0.08, 0.09, 0.32, and 0.23 Bq kg^{-1}, respectively. Hence the mean content of ^{90}Sr in grain products was 0.23 Bq kg^{-1}. The content of ^{137}Cs in the five products was 11.1, 0.29, 2.22, 8.22, and 0.37 Bq kg^{-1}. Hence the mean content of ^{137}Cs in grain products was 4.56 Bg kg^{-1}.

The activity levels in rye flour (100% extraction), wheat flour (75% extraction), and grits were all taken from Tables 5.9.1 and 5.9.2 in Risø Report No. 540[3]. The calculations of the ^{90}Sr level in rye flour (70% extraction) was made similarly to that of the level in wheat flour (75% extraction), i.e. as one-fifth of the whole- grain activity. The ^{137}Cs content in rye flour (70% extraction) was calculated as one-half of the whole-grain level in rye in analogy with the ratio of ^{137}Cs in whole wheat grain to wheat flour (75% extraction)[3]. The ^{90}Sr and ^{137}Cs contents in biscuits were calculated by dividing the levels of the rye flour (100% extraction) by 1.35, since 1 kg flour yields 1.35 kg bread[3].

3.3.4. Potatoes, Other Vegetables, and Fruit

The Danish mean levels for 1987 were used[3], since the local production is insignificant compared with imports from Denmark.

The Danish mean levels were: in potatoes 0.044 Bq ^{90}Sr kg^{-1} and 0.134 Bq ^{137}Cs kg^{-1}, in other vegetables 0.32 Bq ^{90}Sr kg^{-1} and 0.064 Bq ^{137}Cs kg^{-1}, and in fruit 0.065 Bq ^{90}Sr kg^{-1} and 0.16 Bq ^{137}Cs kg^{-1}.

3.3.5. Meat

Nearly all meat consumed in Greenland is assumed to be of local origin. Approximately 10% comes from sheep, 5% from reindeer, 60% from seals, 5% from whales, and 20% from sea birds and eggs.

The activities in reindeer were estimated from 3.2.3. Seal and whale were estimated from 3.2.4. The levels of lamb and sea birds (and eggs) were taken from last year's measurements (Risø-R-550)[4]. Hence the mean levels in Greenland meat from 1987 were 0.019 Bq ^{90}Sr kg^{-1} and 5.6 Bq ^{137}Cs kg^{-1}.

(^{90}Sr: $0.1 \times 0.097 + 0.05 \times 0.16 + 0.6 \times 0.002 + 0.05 \times 0.001 + 0.2 \times 0$
$= 0.019$ Bq kg^{-1})

(^{137}Cs: $0.1 \times 29 + 0.05 \times 50 + 0.6 \times 0.16 + 0.05 \times 0.54 + 0.2 \times 0.44$
$= 5.6$ Bq kg^{-1})

3.3.6. Fish

All fish consumed was of local origin, and the mean levels from 1987 were used, i.e. 0.13 Bq ^{90}Sr kg^{-1} and 0.55 Bq ^{137}Cs kg^{-1}.

3.3.7. Coffee and Tea

The Danish figures for 1987[3] were used for coffee and tea, i.e. 0.41 Bq ^{90}Sr kg^{-1} and 1.23 Bq ^{137}Cs kg^{-1}.

3.3.8. Drinking Water

The geometric mean calculated in 3.2.6 was used as the mean level of ^{90}Sr in drinking water, i.e. 12.4 Bq ^{90}Sr m^{-3}. The ^{137}Cs content was approximately 3 Bq ^{137}Cs m^{-3}.

Tables 3.3.1 and 3.3.2 show the diet estimates of ^{90}Sr and ^{137}Cs, respectively.

Table 3.3.1. Estimate of the mean content of ^{90}Sr in the human diet in Greenland in 1987

Type of food	Annual quantity in kg	Bq ^{90}Sr per kg	Total Bq ^{90}Sr	Percentage of total Bq ^{90}Sr in food
Milk and cream	78	0.071	5.54	9.2
Cheese	2.5	0.50	1.25	2.1
Grain products	95.6	0.23	21.99	36.7
Potatoes	32.8	0.044	1.44	2.4
Vegetables	5.5	0.32	1.76	2.9
Fruit	13.5	0.065	0.88	1.5
Meat and eggs	45.6	0.019	0.87	1.5
Fish	127.6	0.013	16.59	27.7
Coffee and tea	7.3	0.41	2.99	5.0
Drinking water	548	0.012	6.58	11.0
Total			59.89	

The mean annual calcium intake is estimated to be 0.56 kg (approx. 0.2-0.25 kg creta praeparata). Hence the $^{90}Sr/Ca$ ratio in Greenland total diet in 1987 was 107 Bq ^{90}Sr (kg Ca)$^{-1}$ or 2.9 pCi ^{90}Sr (g Ca)$^{-1}$ and the daily intake was 0.16 Bq ^{90}Sr or 4.4 pCi ^{90}Sr.

Fig. 3.3.1. Strontium-90 in Greenland diet, 1962-1987.

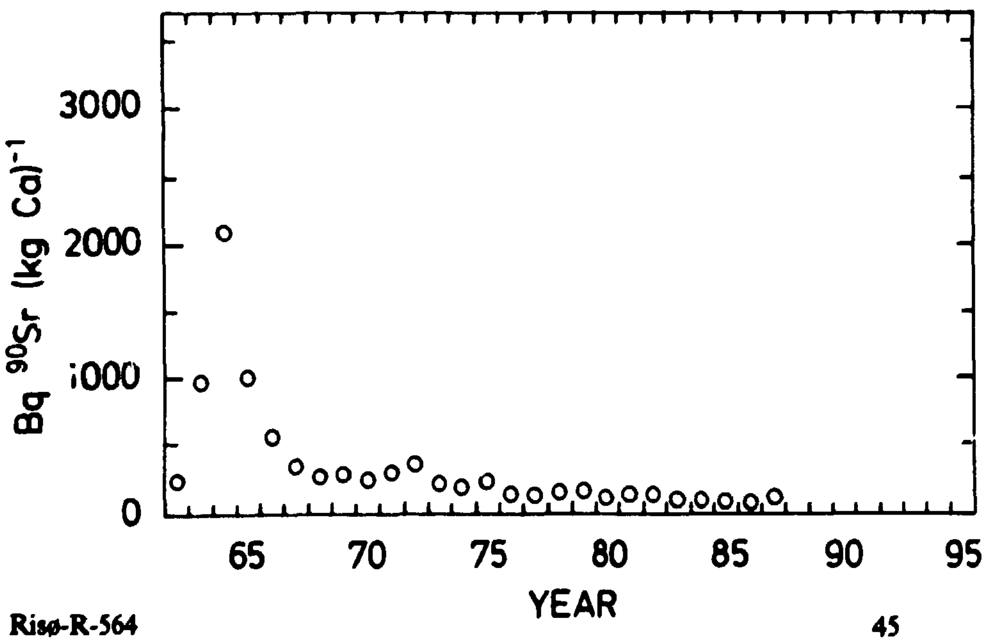
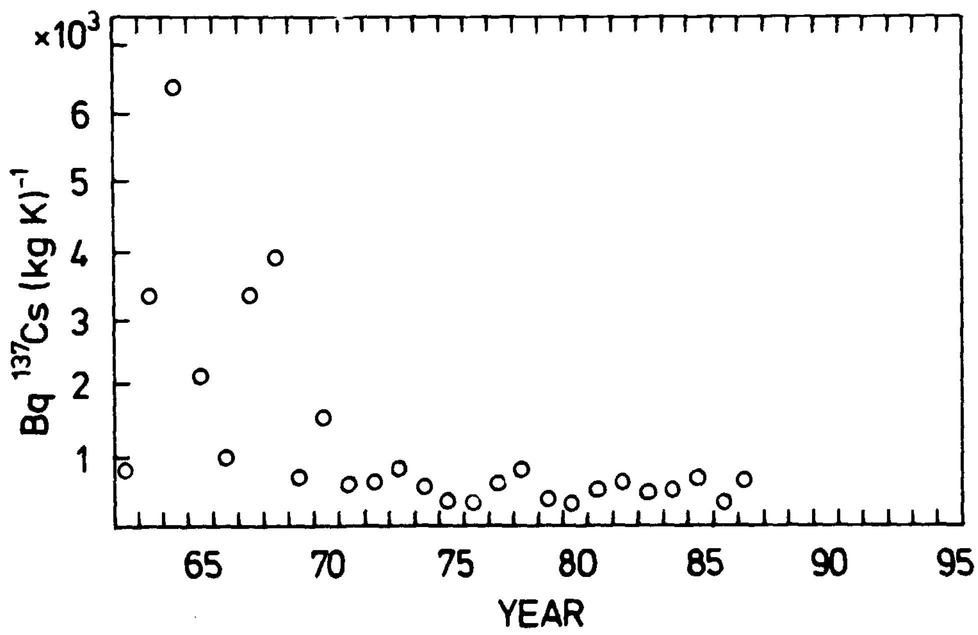


Table 3.3.2. Estimate of the mean content of ^{137}Cs in the human diet in Greenland in 1987

Type of food	Annual quantity in kg	Bq ^{137}Cs per kg	Total Bq ^{137}Cs	Percentage of total Bq ^{137}Cs in food
Milk and cream	78	0.60	46.80	5.7
Cheese	2.5	0.43	1.08	0.1
Grain products	95.6	4.56	435.94	52.7
Potatoes	32.8	0.134	4.40	0.5
Vegetables	5.5	0.064	0.35	0
Fruit	13.5	0.16	2.16	0.3
Meat and eggs	45.6	5.6	255.36	30.9
Fish	127.6	0.55	70.18	8.5
Coffee and tea	7.3	1.23	8.98	1.1
Drinking water	548	0.003	1.64	0.2
Total			826.89	

The mean annual potassium intake is estimated to be approx. 1.2 kg. Hence the $^{137}Cs/K$ ratio becomes 690 Bq ^{137}Cs (kg K)$^{-1}$ or 18.6 pCi ^{137}Cs (g K)$^{-1}$). The daily intake in 1987 from food was 2.27 Bq ^{137}Cs or 61 pCi ^{137}Cs.

Fig. 3.3.2. Cesium-137 in Greenland diet, 1962-1987.



3.3.9. Discussion

The most important ^{90}Sr source in the Greenland diet is still grain products, which contribute 37% of the total ^{90}Sr content in the diet. Approximately 60% of the ^{90}Sr in the food consumed in Greenland in 1987 originated from imported (Danish) food.

Meat is still an important ^{137}Cs source in the Greenland diet, contributing 31% of the total content in 1987. However, grain contributed with 53% to the intake of ^{137}Cs with Greenland diet in 1987, which was due to the Chernobyl contamination of Danish grain in 1986. Approximately 40% of the ^{137}Cs in the Greenland diet in 1987 came from local products. This is lower than had been observed earlier, because the Danish imported food, in particular grain and milk, was contaminated by Chernobyl ^{137}Cs.

The ^{90}Sr contents in the total diet in 1987 was 1.36 times the 1986 level.

The ^{137}Cs level was twice that found in 1986. As discussed earlier[2)], the great variations from year to year are primarily due to the variations in the ^{137}Cs levels in the lamb and reindeer samples obtained. The contribution of Chernobyl ^{137}Cs to Greenland meat was far less than these variations.

The ^{90}Sr content of the Greenland diet in 1987 was equal to the Danish mean content[3)], and 1.1 times the Faroese level[1)]. The ^{137}Cs level in the total diet in Greenland was 1.45 times the Danish and 24% of the Faroese diet level.

3.4. Conclusion

3.4.1.

The ^{90}Sr fallout rate in 1987 was less than 1 Bq m^{-2}. The deposition of ^{137}Cs from the Chernobyl accident (resuspension) varied from nearly nil to 7 Bq m^{-2}.

3.4.2.

The food consumed in Greenland in 1987 contained on the average 107 Bq ^{90}Sr (kg Ca)$^{-1}$, and the daily mean intake of ^{137}Cs was estimated as 2.27 Bq. The most important ^{90}Sr contributor to the diet was grain products; these accounted for 36% of the total ^{90}Sr content of the diet. Cesium-137 originated mainly from grain and meat (reindeer and lamb), contributing 84% of the total ^{137}Cs content of the diet. Chernobyl radiocesium was detectable in Greenland food, but did not influence the ^{137}Cs level significantly.

3.4.3.

No ^{90}Sr analyses of human bone samples have hitherto been carried out on the population of Greenland. Considering the estimated ^{90}Sr levels in the diet, it seems probable[4)], however, that the 1987 ^{90}Sr levels of humans in Greenland were on the average rather similar to those found in Denmark, i.e. the mean levels in human bone in Greenland were approximately 22 Bq ^{90}Sr (kg Ca)$^{-1}$ (vertebrae). From diet measurements, the ^{137}Cs content in Greenlanders was estimated as 2000 Bq ^{137}Cs (kg K)$^{-1}$.

4. Environmental Radioactivity in the North Atlantic Region

4.1. Monthly Surface Sea Water Samples from Utsira, Norway

Institute of Energy Technology, Kjeller, Norway, collects monthly sea water samples at Utsira 59°19'N, 4°54'E in SW-Norway. From this station it is possible to monitor the radioactivity in the Norwegian Coastal Current, which carries the activity from the North Sea to the Arctic waters in the north.

Tables 4.1.1 and 4.1.2 show the results from 1987 and 1986. 45% of the ^{137}Cs in the sea water from Utsira in 1987 was from Chernobyl. This contribution was rather constant throughout the year (relative S.D.: 8%).

Table 4.1.1. Radiocesium and strontium-90 in surface sea water collected in 1987 from Utsira, Norway. 59°19'N, 4°54'E. (Unit: Bq m^{-3})

Date	^{90}Sr	^{137}Cs	^{134}Cs / ^{137}Cs	Salinity in ‰	^{99}Tc
March 19	10.0				
April 12	13.4	59	0.20	28.6	lost
May 16	11.2	56	0.162	31.3	0.62
June 19	10.8	50	0.171	33.2	1.04
July 27	13.3	54	0.184	32.0	1.26
Aug 31	14.0	52	0.147	30.8	1.19
Sept 28	13.0	48	0.161	32.3	1.46
Nov 3		48	0.168	29.0	1.71
Mean	12.2	52		31.0	1.21
1 S.D.	1.54	4.2		1.70	0.37
Relative S.D.	13%	8%		5%	31%

Table 4.1.2. Technetium-99 in surface sea water collected in 1986 from Utsira, Norway. 59°19'N, 4°54'E. (Unit: Bq m^{-3})

Date	^{99}Tc Bq m^{-3}	Salinity in ‰
April 23	1.68	32.3
May 20	1.02	30.2
June	2.17	29.4
July	2.17	32.0
Octocer 28	1.40	32.4
November 17	1.45	33.1
December 5	1.56	33.0
Mean	1.64	31.8
1 S.D.	0.42	1.42
Relative S.D. %	26%	4%

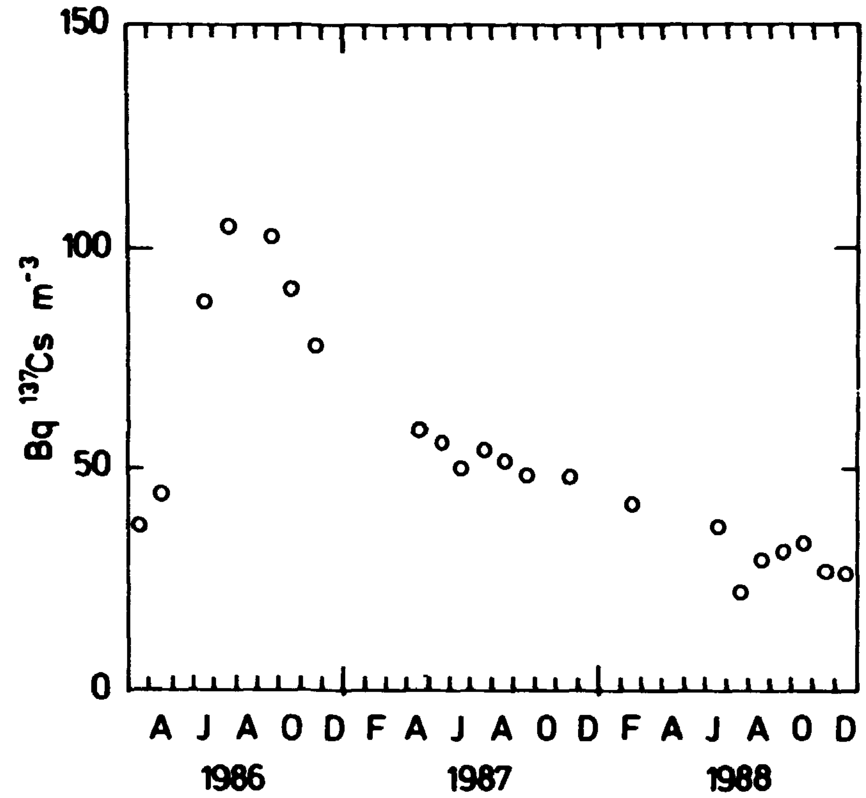
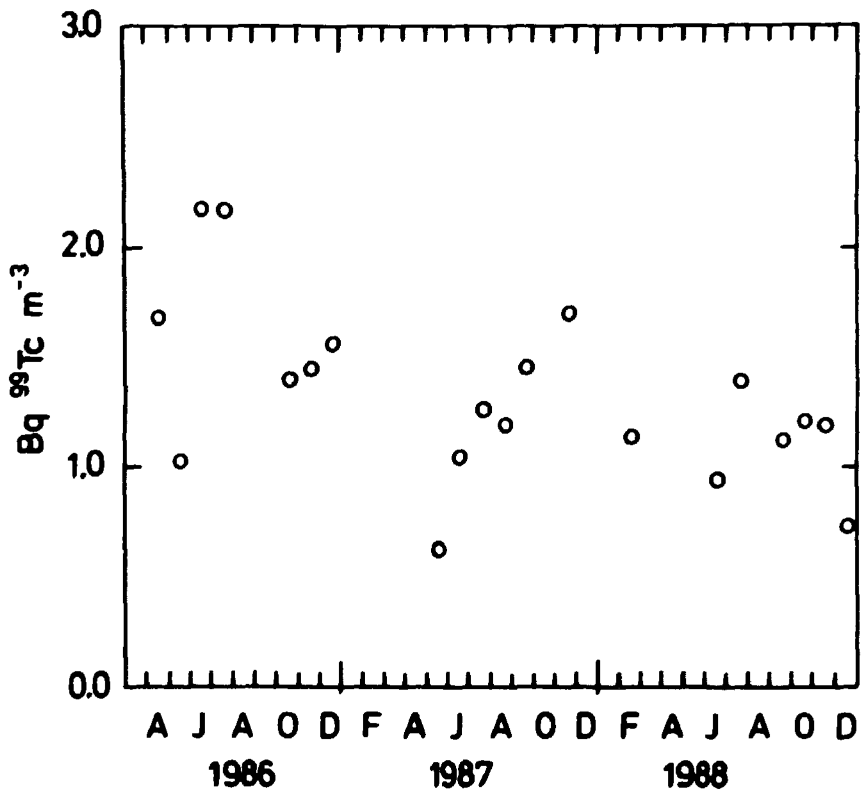


Fig. 4.1.1. Cesium-137 in surface sea water collected at Utsira (59°19'N, 4°54'E). (Unit: Bq m^{-3}).

Fig. 4.1.2. Technetium-99 in surface sea water collected at Utsira (59°19'N, 4°54'E). (Unit: Bq m^{-3}).



4.2. Surface Sea Water Samples Collected in West Greenland Waters in July 1987 by The Greenland Fisheries and Environmental Research Institute

The sampling in 1987 was the sixth since this programme began in July 1983; 108 ^{90}Sr and 116 ^{137}Cs analyses have been carried out. The data were treated by two-sided anovas (cf. Tables 4.2.2-4.2.3).

It appears that the variation between samplings was considerably larger for ^{90}Sr than for ^{137}Cs, although both were highly significant. Thus, from July 1983 to July 1987, the ^{90}Sr concentrations decreased by a factor of 2.1, while the ^{137}Cs decreased by a factor of only 1.2. For ^{137}Cs the variation between locations was significant; the southern locations at 64°N contained 1.4 times higher concentrations than the northern at about 71°N. There was no significant local variation for ^{90}Sr. The explanation for these significant differences between the distributions of ^{90}Sr and ^{137}Cs is that the discharges of ^{137}Cs from Sellafield have partly compensated for the decrease in global fallout concentrations. This compensation does not take place for ^{90}Sr. Hence we see a more rapid decrease in time for this nuclide. Furthermore, the Chernobyl accident also contributed to this compensation for ^{137}Cs in 1987. As the Sellafield input comes with the East Greenland Current, it makes sense that the highest ^{137}Cs concentrations are found at the southern stations at West Greenland because these stations first receive the water from the East Greenland Current. The ^{137}Cs determinations of bulked samples in 1987 (cf. Table 4.2.1) show that the percentage of Chernobyl ^{137}Cs was nearly the same at the southern stations (~64°-67°N) as at the northern locations (68°-71°N), namely 8 and 7%, respectively (cf. also 4.6).

Table 4.2.1. Strontium-90 and cesium-137 in surface sea water off West Greenland in July 1987

Latitude N	Longitude W	Name of Location	^{90}Sr Bq m^{-3}	^{134}Cs Bq m^{-3}	^{137}Cs Bq m^{-3}	Salinity in ‰
63°59'	52°22'	Fylla Banke (Nuuk)	2.6		4.6	31.9
63°55'	53°07'	Fylla Banke (Nuuk)	3.1		lost	lost
63°48'	53°55'	Fylla Banke (Nuuk)	2.6		4.7	33.4
65°06'	53°00'	Sukkertoppen (Maniitsoq)	2.4		5.0	32.7
65°06'	53°59'	Sukkertoppen (Maniitsoq)	2.6	0.131	4.6	33.5
65°06'	54°58'	Sukkertoppen (Maniitsoq)	2.5		5.0	33.4
66°53'	54°08'	Holsteinsborg (Sisimiut)	2.1		4.2	33.4
66°46'	55°35'	Holsteinsborg (Sisimiut)	2.3		4.3	33.5
66°41'	56°37'	Holsteinsborg (Sisimiut)	2.4		4.1	33.5
67°34'	57°10'	Intermediate station	2.6		4.2	33.2
68°00'	55°00'	Egedesminde (Aasiaat)	2.3		3.7	33.8
68°04'	56°00'	Egedesminde (Aasiaat)	2.4		4.1	33.5
68°08'	57°17'	Egedesminde (Aasiaat)	2.3		3.6	31.7
68°14'	58°40'	Egedesminde (Aasiaat)	2.2		4.5	31.9
68°32'	58°10'	Disko rende	2.1		4.3	32.5
68°43'	55°03'	Disko rende	1.9	0.107	4.2	33.4
69°08'	58°25'	Disko rende	2.0		3.6	32.6
69°30'	56°00'	Disko fjord	2.3		3.6	33.4
70°45'	54°60'	Nugssuag	2.1		2.9	32.0
70°45'	57°00'	Nugssuag	2.1		3.5	32.3
70°41'	59°30'	Nugssuag	2.2		3.9	31.6

Table 4.2.2. Anova of ln Bq ^{90}Sr m^{-3} surface water collected off West Greenland July 1983 - July 1987 (cf. Table 4.2.1 and Risø-R-510, 528 and 541[4])

Variation	SSD	f	s^2	v^2	P
Between samplings	6.312	5	1.262	58.40	>99.95
Between locations	0.624	31	0.020	0.931	-
Interaction	1.513	70	0.022	1.07	-
Remainder	0.020	1	0.020		

Table 4.2.3. Anova of ln Bq ^{137}Cs m^{-3} surface water collected off West Greenland July 1983 - July 1987 (cf. Table 4.2.1 and Risø-R-510, 528 and 541[4])

Variation	SSD	f	s^2	v^2	P
Between samplings	0.751	5	0.150	11.60	>99.95
Between locations	1.365	32	0.043	3.29	>99.95
Interaction	0.998	77	0.013	0.63	-
Remainder	0.021	1	0.021		

4.3. »Polarstern« Cruise to the Greenland Sea June 1987

Figure 4.3.1 shows the distribution of ^{90}Sr in surface sea water in the Greenland Sea in 1987. A few deep water samples are also included. The input from Sellafield appears (in the lower right corner of the figure) around 70°N and 15°E.

Input of Arctic Ocean water with enhanced global fallout concentrations is seen in the East Greenland Current (EGC) (cf. the upper left part of the map). The lowest ^{90}Sr concentrations are seen in the central part of the Greenland Sea (~ 75°N, ~ 0°).

The ^{137}Cs concentrations are shown in Fig. 4.3.2. The contribution from Chernobyl decreases by an order of magnitude when we move westwards. Figure 4.3.3 shows the relative contribution of ^{137}Cs from Chernobyl. The relatively high contribution at 72°27'N, 8°11'W (48%) may be due to upwelling of deeper water with Chernobyl ^{137}Cs. In the EGC the Chernobyl signal is a few per cent of the total ^{137}Cs.

Figure 4.3.4 shows the $^{137}Cs/^{90}Sr$ in the Greenland Sea. If we look at the non-Cernobyl ratios we notice that nearly all of them are greater than the expected ratio in global fallout in the Arctic, which is about 1.2-1.5[6]. In the EGC closest to Greenland the ratio approaches that in global fallout.

Figure 4.3.5 shows the ^{99}Tc concentrations. The highest levels were seen in the northern part of the Fram Strait around 80°N. A single high value was seen at 74°10'N 8°00'W (107 mBq m^{-3}). Neighbouring samples collected at 200 m depth may suggest that upwelling of deeper water was due to the enhanced level found in this sample. Figure 4.3.6 shows the $^{99}Tc/^{90}Sr$; these data support the theory of upwelling as the reason for the above-mentioned enhanced level.

Table 4.3. Radionuclides in sea water collected in Fram Straits and Greenland Sea in June 1987

Position N	E or W	Date	Depth in m	Temp. in °C	Salinity in ‰	^{90}Sr Bq m^{-3}	^{99}Tc mBq m^{-3}	^{134}Cs Bq m^{-3}	^{137}Cs Bq m^{-3}	^{238}Pu mBq m^{-3}	$^{239,240}Pu$ mBq m^{-3}	^{241}Am mBq m^{-3}
78°49'	00°10'W	June 10	2	1.5	34.1	2.9	69	1.72	10.4			
79°10'	09°48'W	June 12	2	-1.5	32.4	4.2	47 ± 0		6.9			
79°00'	12°25'W	June 13	2	-1.6	32.4	4.3	147		6.4 ± 0.1			
79°52'	04°21'W	June 14	2	-1.6	32.3	5.0	122	0.06 A	10.2	0.52	12.5	lost
80°00'	04°29'E	June 16	2	1.5	34.2	2.8	104	1.47	10.4			
78°54'	06°43'E	June 17	2	4.0	34.5	2.5	86	2.4	12.4	0.69	15.0	2.0
76°39'	02°14'W	June 18	2	0.0	33.2	3.3	66	1.06	9.2		15.3	1.7
75°30'	06°39'W	June 19	2	-0.5	33.1	3.5	98	0.65	9.3			
75°33'	08°49'W	June 19	2	-0.8	33.0	4.3	90	0.35 A	9.5			
75°35'	11°22'W	June 20	2	-1.7	32.4	lost	53	0.094	8.1			
75°33'	11°39'W	June 20	215	1.5	34.9	2.4	110		7.0			
75°26'	10°47'W	June 21	2	-1.6	32.9	3.5	84	0.36 A	8.8			
75°26'	10°47'W	June 21	200	1.0	35.0	2.1	84	1.61 A	10.9			
75°09'	12°28'W	June 22	2	-1.7	32.4	4.2	82 ± 20	0.075	8.0			
74°10'	08°00'W	June 23	2	2.7	33.8	2.5	107	0.54	7.1		17.1	2.0
72°27'	08°11'W	June 24	2	2.6	34.0	2.6	44	1.81 A	10.0			
71°21'	08°36'W	June 25	2	2.9	34.1	2.8	57	0.49	8.9		16.4	1.45
72°00'	15°00'W	June 25	2	-	32.9	2.4	70	0.52	6.5			
72°22'	16°47'W	June 26	2	-0.6	32.2	3.6	41		7.0			
72°30'	17°31'W	June 26	2	0.0	31.9	4.2	74	0.096	6.5		12.0	2.3
73°27'	13°19'W	June 27	2	0.1	32.2	3.6	56	0.66	8.8		11.3	2.0
74°17'	06°15'W	June 28	2	2.6	34.2	2.3	26		5.8			
74°30'	02°35'W	June 28	2	2.2	34.7	2.2	37	0.21	5.6		13.0	B.D.L.
74°30'	02°35'W	June 28	3570	-1.05	34.9	0.84		0.12 A	1.08			
74°38'	01°03'E	June 29	2	1.9	34.8	2.1	31		5.7			
74°38'	01°03'E	June 29	10	1.9	34.8	2.1			5.1			
74°42'	03°46'E	June 29	10	2.8	34.9	2.7			6.4			
73°32'	08°23'E	June 30	10	6.0	34.9	3.1		2.2	12.5			
73°11'	09°43'E	June 30	10	5.9	35.1	2.5		2.6	12.6			
72°51'	11°03'E	June 30	10	6.3	35.1	2.6		2.5	12.5			
72°19'	12°46'E	June 30	10	6.8	35.1	3.8		3.5	16.0			
71°57'	14°00'E	June 30	10	6.7	34.9	4.0		4.8	21.7			
71°35'	15°16'E	June 30	10	6.7	34.9	3.8		4.4	21.0			
71°07'	17°00'E	July 1	10	6.6	34.3	6.3		8.6	40			
70°38'	18°33'E	July 1	10	6.4	34.2	6.3		9.2	41			
70°25'	19°39'E	July 1	10	6.2	34.4	6.7		8.3	40			
70°09'	20°15'E	July 1	10	5.7	34.3	6.6		8.9	39			

The error term is 1 S.E. of the mean of double determinations.

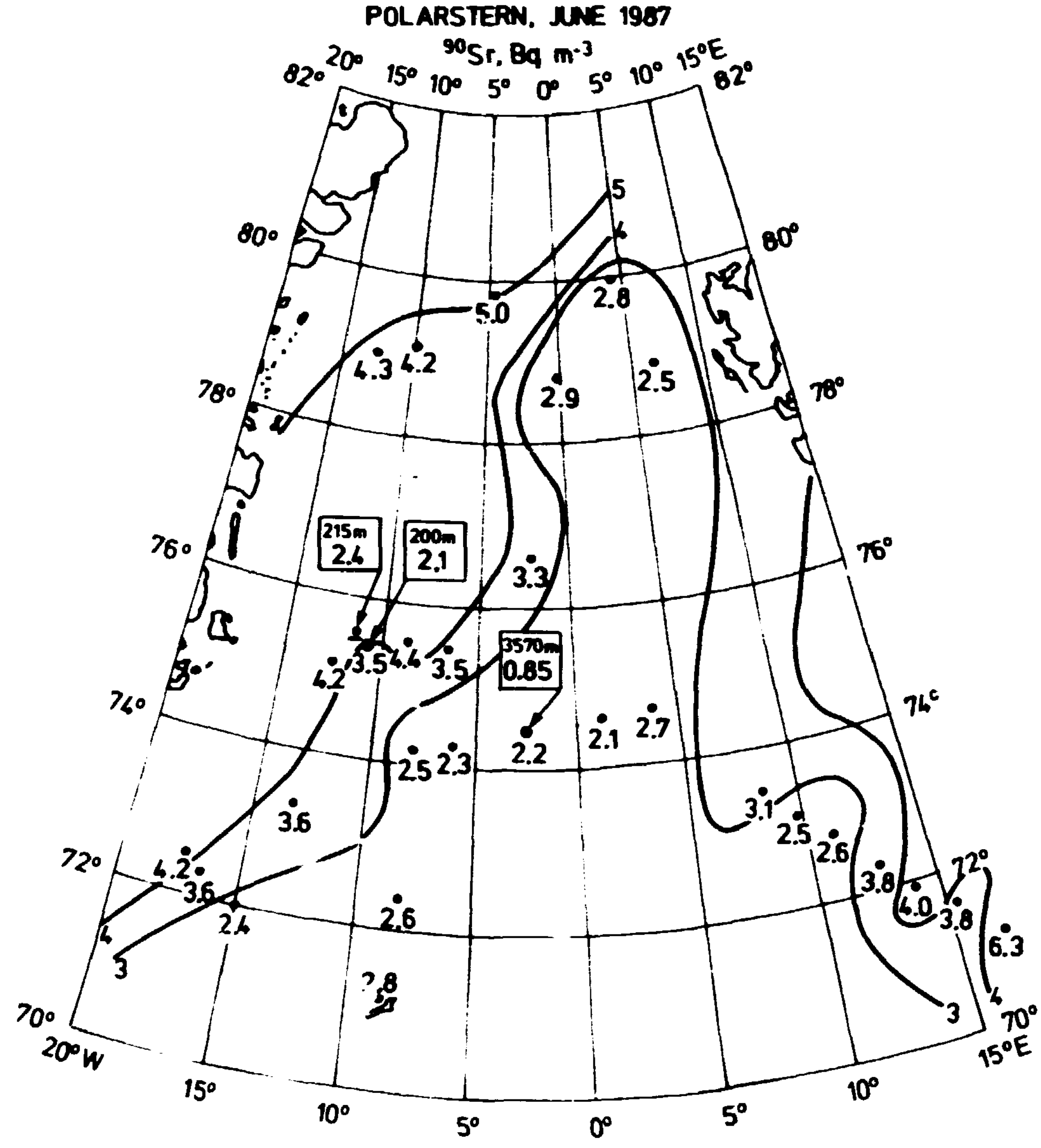


Fig. 4.3.1. Strontium-90 in the Greenland Sea, June 1987. Surface water samples except where depths are given.

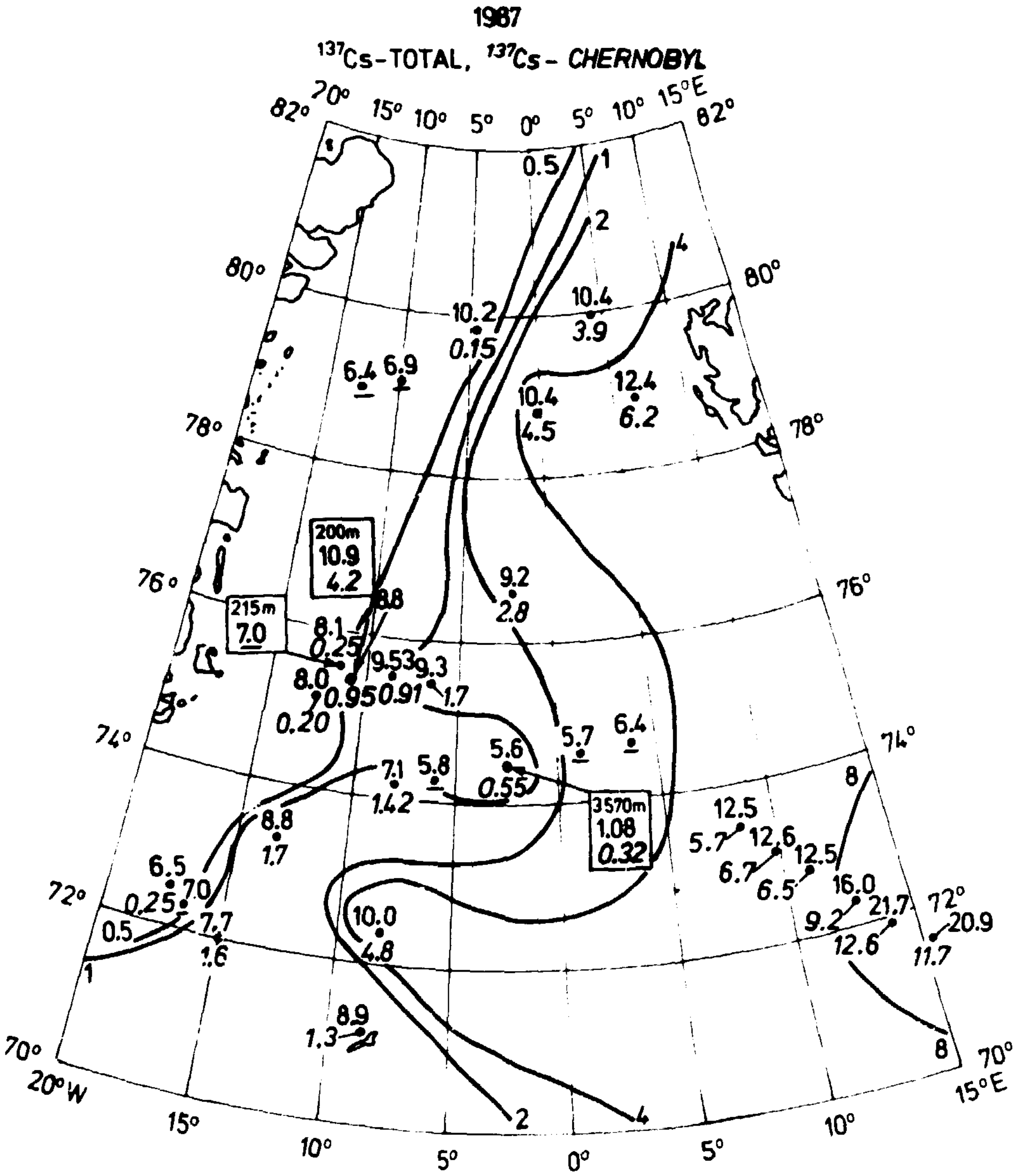


Fig. 4.3.2. Cesium-137 in the Greenland Sea, June 1987. Measured total ^{137}Cs (upper figures) and calculated Chernobyl-derived ^{137}Cs based on ^{134}Cs measurements (lower figures). Surface water samples except where depth are given. The isolines show the ^{137}Cs-Chernobyl concentrations.

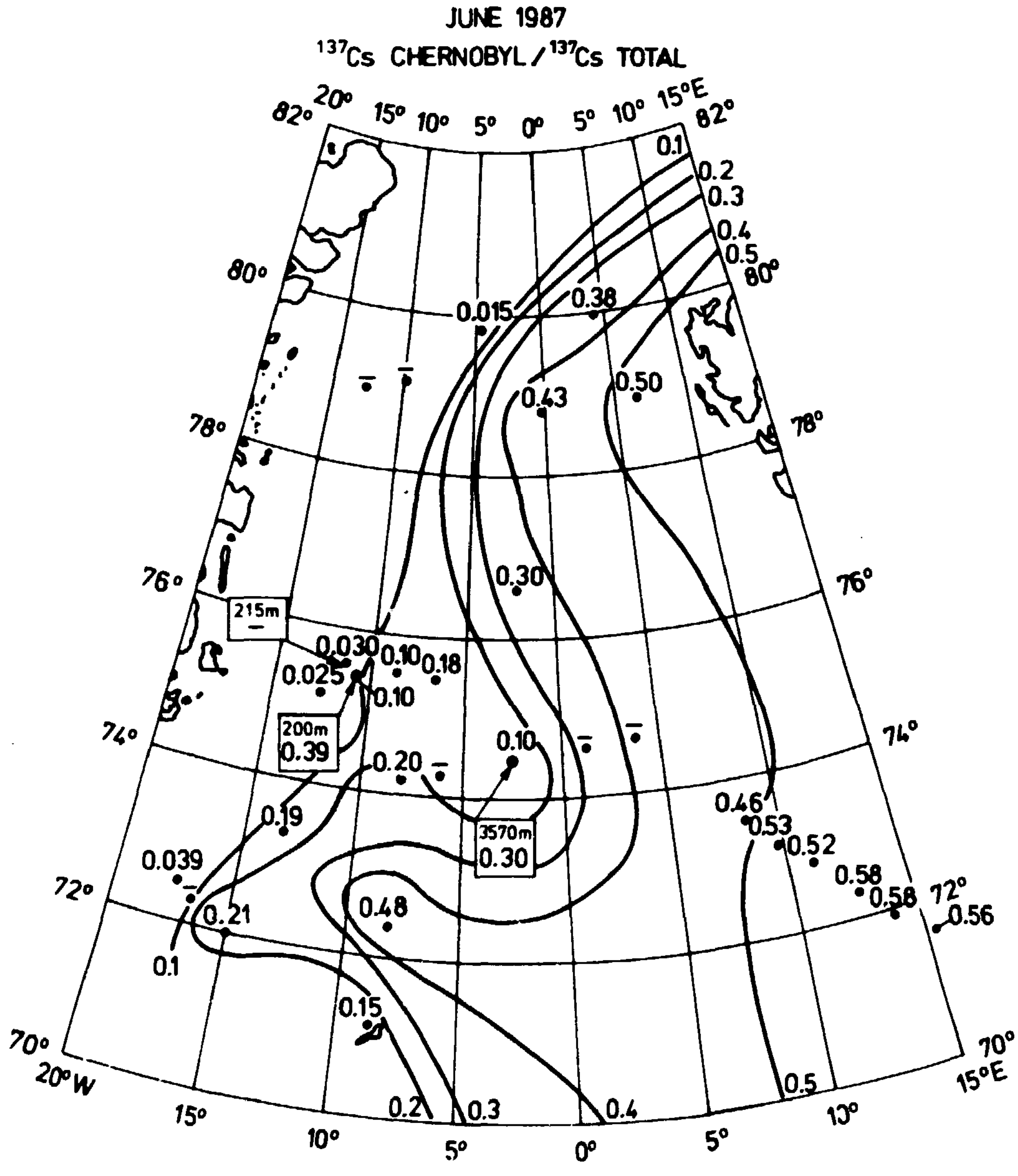


Fig. 4.3.3. Fraction of ^{137}Cs originating from Chernobyl, Greenland Sea, June 1987. Based on data given in Fig. 4.3.2.

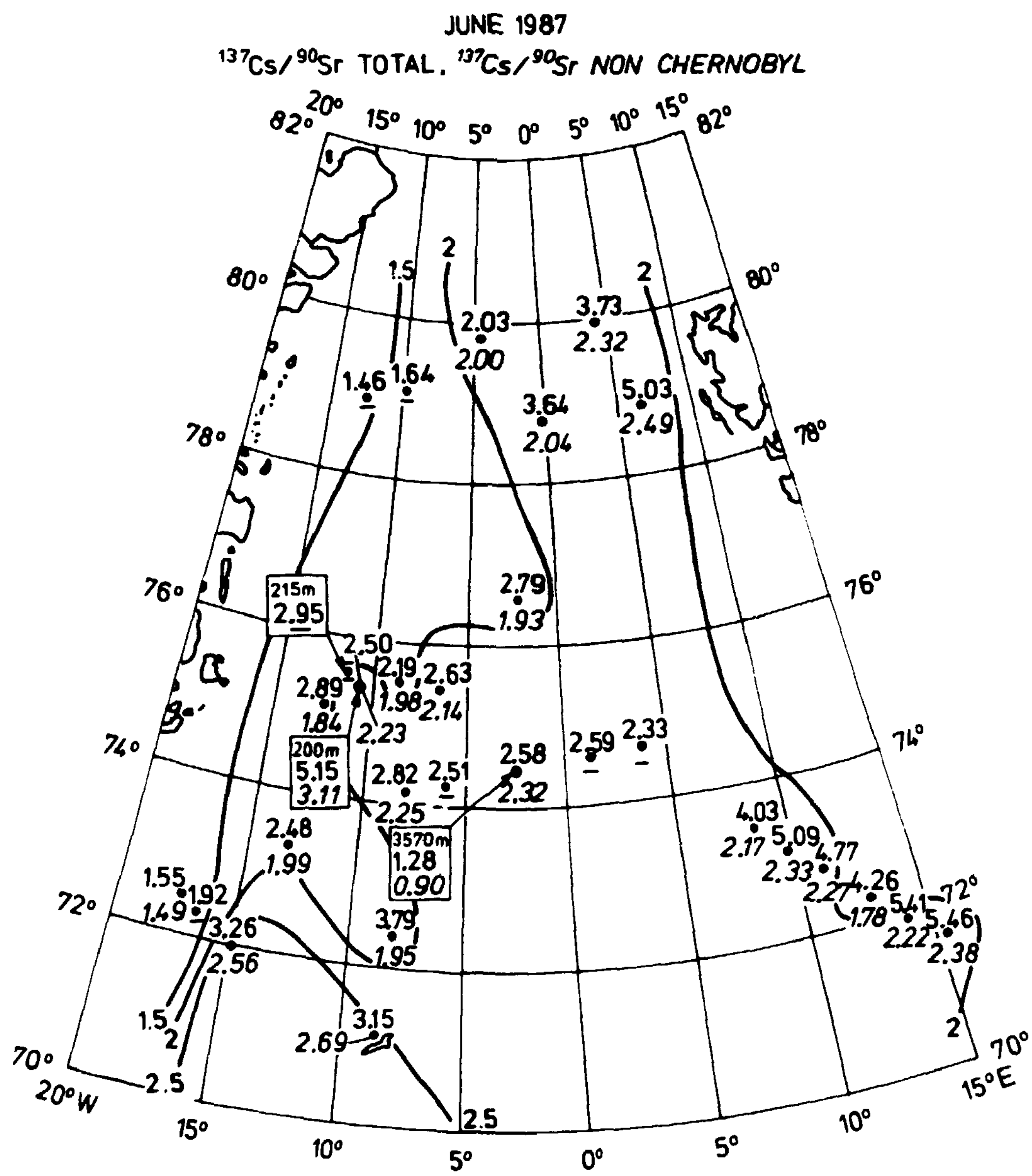


Fig. 4.3.4. Cesium-137/strontium-90 ratios based on data given in Figs. 4.3.2 and 4.3.1. Upper figures refer to total ^{137}Cs; lower figures to Chernobyl-derived ^{137}Cs. The isolines show the $^{137}Cs/^{90}Sr$ non-Chernobyl ratios.

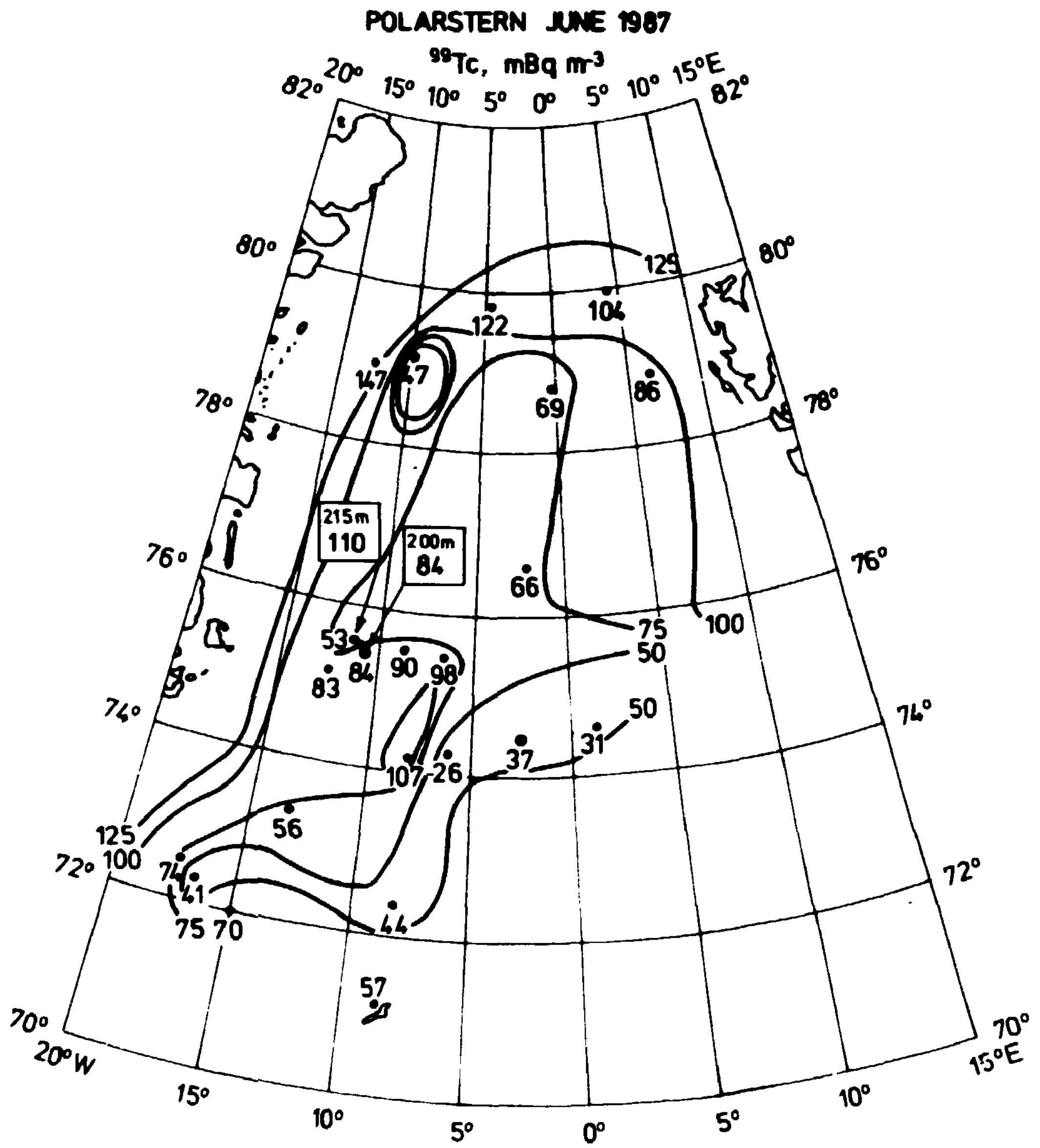


Fig. 4.3.5. Technetium-99 in the Greenland Sea, June 1987. Surface water samples except where depths are given.

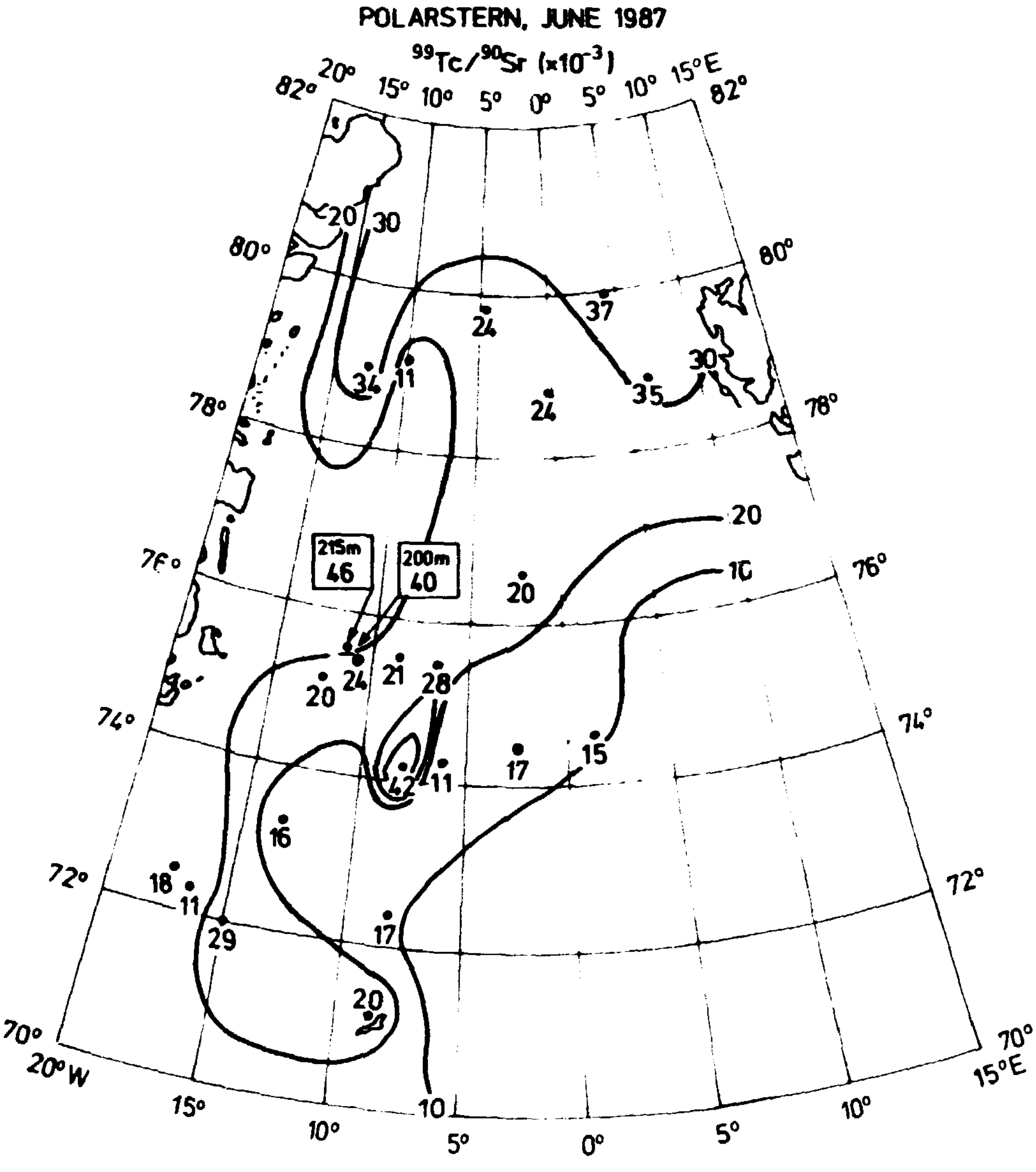


Fig. 4.3.6. Technetium-99/strontium-90 ratios based on data given in Figs. 4.3.5 and 4.3.1. Greenland Sea, June 1987.

4.4. Transuranics in the Greenland Sea in "Polarstern Samples" Collected in June 1987

Tables 4.3 and 4.4 show the results of Pu and Am analyses of total sea water and particulates in sea water samples obtained from filtration of the water through a 0.45 μ millipore cartridge filter. The particulate Pu fraction was determined in 7 samples. The mean fraction of particulate Pu was 15.0 ± 5.2% (±1 S.D.); for 5 Am samples we found 10.4 ± 6.3%.

The mean concentration of $^{239,240}Pu$ in total sea water from the Greenland Sea was 14.1 ± 2.2 mBq m^{-3} (±1 S.D.; N = 8) and the mean ^{241}Am concentration was 1.91 ± 0.29 mBq m^{-3} (±1 S.D.; N = 6). Two samples were analysed for ^{238}Pu. The mean $^{238}Pu/^{239,240}Pu$ was 4.4 ± 0.28% (±1 S.D.) and the mean $^{241}Am/^{239,240}Pu$ was 13.5 ± 4.0% (±1 S.D.; N = 6). In July 1983[6] the mean $^{239,240}Pu$ concentration was 12 mBq m^{-3} in the Greenland Sea. Hence we conclude that the Pu concentrations have been rather constant in this area for the last four years.

Table 4.4. Particulate transuranics in sea water collected on 0.45 μ Millipore filters in the Fram Strait and Greenland Sea in June 1987

Position N	E or W	Date	Depth in m	^{238}Pu mBq m^{-3}	$^{239,240}Pu$ mBq m^{-3}	^{241}Am mBq m^{-3}
79°00'	12°25'W	June 13	2	B.D.L.	B.D.L.	B.D.L.
79°52'	04°21'W	June 14	2	B.D.L.	B.D.L.	B.D.L.
78°54'	06°43'E	June 17	2	0.11 B	1.7	0.26
76°39'	02°14'W	June 18	2	0.14 B	3.0	0.184
74°10'	08°00'W	June 23	2	0.085 B	2.1	0.126
71°21'	08°36'W	June 25	2	0.30 B	4.0	0.28
72°30'	17°31'W	June 26	2	0.10 B	1.19	0.064
73°27'	13°19'W	June 27	2	0.18 B	1.57	B.D.L.
74°30'	02°35'W	June 28	2	0.044 B	1.74	B.D.L.

4.5. "Bjarni Sæmundson" Cruise to the Denmark Strait and the Southern Greenland Sea in September 1987 (GSP Project)

Figure 4.5 and Table 4.5 show the results of the ^{90}Sr and radiocesium analyses from samples collected by "Bjarni Sæmundson" in September 1987. The lowest ^{90}Sr concentrations were observed around Iceland, the highest were seen in the East Greenland Current (EGC).

The ^{137}Cs concentrations were also highest in EGC. Chernobyl ^{137}Cs was present in the eastern samples (cf. Table 4.5). The mean contribution from Chernobyl in these samples was 38%.

A single sample from the Denmark Strait (64°04'N 52°09'W) contained surprisingly high radiocesium concentrations. The ^{134}Cs content in this sample suggested that about 90% of the ^{137}Cs in this sample was from Chernobyl. This seems high when we compare measured values of this isotope with neighbouring samples and with the ^{90}Sr content in the sample. From the ^{90}Sr concentration we would expect a global fallout background of ^{137}Cs of

SEPT 1987
BJARNI SÆMUNDSON

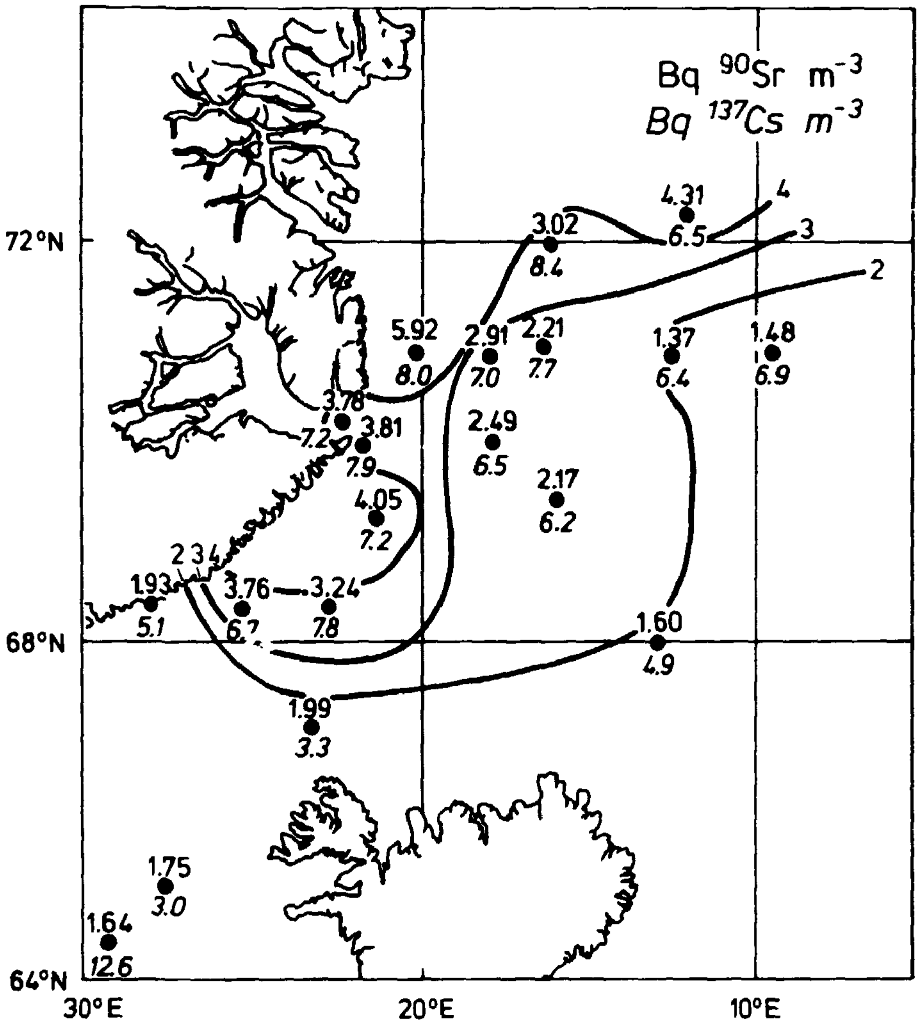


Fig. 4.5. Strontium-90 and cesium-137 in surface sea water collected in the Greenland Sea and Denmark Straits in September 1987. The isolines show the strontium-90 concentrations. (Unit: Bq m^{-3}).

Table 4.5. Radionuclides in surface sea water collected from "Bjarni Sæmundsen" (Greenland Sea Project) in the Greenland Sea and Denmark Strait in September 1987. (Unit: Bq m⁻³)

Position N	W	^{90}Sr	^{134}Cs	^{137}Cs	Salinity in ‰
64°20'	27°57'	1.64	4.18	12.6	34.9
68°00'	12°40'	1.60	0.74 A	4.9	34.4
69°28'	15°26'	2.17		6.2	34.3
71°00'	12°15'	1.37	0.86 A	6.4	34.5
71°00'	9°30'	1.48	0.93 A	6.9	34.6
72°03'	16°18'	3.02	0.92 A	8.4	29.3
72°13'	11°30'	4.31	1.05 A	6.5	31.8
71°00'	16°16'	2.21		7.7	34.3
71°00'	18°16'	2.91		7.0	32.3
71°00'	20°06'	5.92		8.0	30.4
70°00'	17°56'	2.49		6.5	33.9
70°15'	21°52'	3.78		7.2	28.5
70°00'	21°47'	3.81		7.9	30.5
67°10'	22°52'	1.99		3.3	34.6
68°30'	25°55'	3.76		6.7	30.6
68°30'	22°35'	3.24	0.4 B	7.8	33.6
68°30'	28°55'	1.93		5.1	34.2
69°31'	21°16'	4.05		7.2	32.5
65°14'	27°30'	1.75		3.0	35.0

$1.45 \times 1.64 = 2.4$ Bq m^{-3}. If the remaining ^{137}Cs was from Chernobyl, i.e. 10.2 Bq m^{-3}, the ^{134}Cs/^{137}Cs in the Chernobyl debris would be $4.18/10.2 = 0.41$. The theoretical ratio in September 1987 was 0.36. Thus, considering the uncertainties of the ^{134}Cs and ^{137}Cs determinations we cannot exclude the high Chernobyl contribution in this sample.

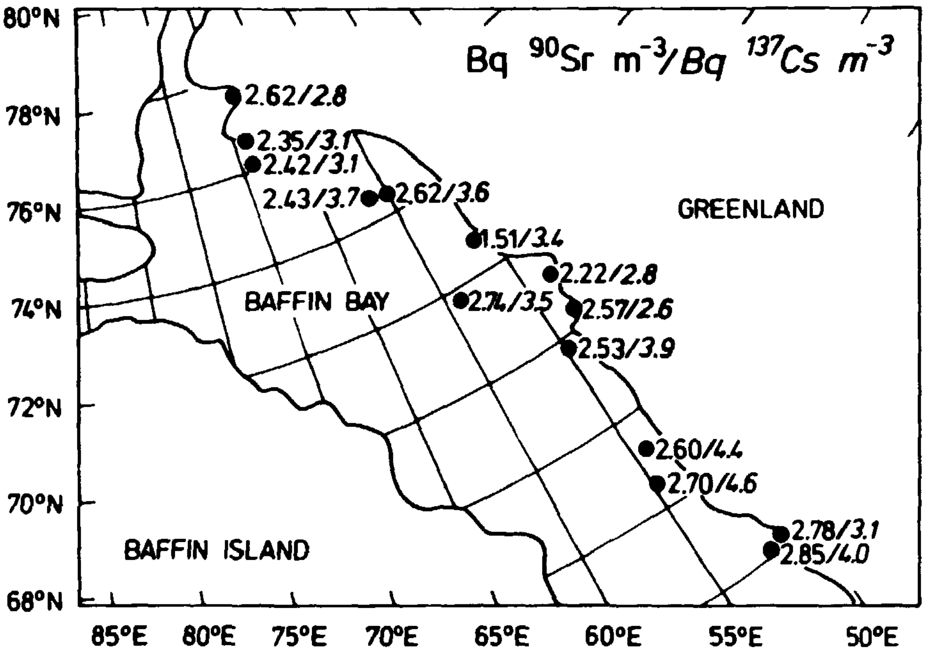
4.6. Cruise Godthåb - Thule by the Greenland Environmental Research Institute in August-September 1987

Surface sea water samples were collected in August from Godthåb to Thule and back again in September by the Greenland Environmental Research Institute (Table 4.6 and Fig. 4.6). The samples collected in August were combined into one sample for the ^{134}Cs determination, and so were the September samples. The contributions of ^{137}Cs from Chernobyl in the two sets of samples were 17% and 18%, respectively. The contribution of Chernobyl ^{137}Cs in West Greenland sea water increased from 7-8% in July to 17-18% in September (cf. 4.2). The samples collected on the way home from Thule in September were closer to land than those collected on the way out. The ^{137}Cs concentrations were lower in the coastal samples than in those farther from land. In general, this was the case for ^{90}Sr as well.

Table 4.6. Radionuclides in surface sea water collected off West Greenland in August-September 1987. (Unit: Bq m⁻³)
(These samples were obtained from Rune Dietz, The Greenland Environmental Research Institute)

Position N	W	Date	^{90}Sr	^{134}Cs	^{137}Cs	Salinity in ‰
64°04'	52°09'	24/8	2.85		4.0	27.7
66°30'	54°49'	25/8	2.70		4.6	32.5
69°41'	55°08'	26/8	2.53		3.9	33.0
71°39'	59°20'	27/8	2.74		3.5	29.9
74°26'	62°41'	28/8	2.43	0.156	3.7	30.5
76°09'	69°29'	29/8	2.42		3.1	30.0
76°35'	69°00'	30/8	2.35		3.1	29.0
77°32'	68°30'	1/9	2.62		2.8	30.4
74°24'	59°15'	5/9	2.62		3.6	30.8
72°44'	55°40'	8/9	1.51	0.155	3.4	31.9
71°14'	53°26'	11/9	2.22		2.8	31.2
70°16'	53°26'	12/9	2.57		2.6	32.4
67°11'	52°13'	15/9	2.60		4.4	32.0
64°14'	51°27'	17/9	2.78		3.1	24.9

Fig. 4.6. Strontium-90 and cesium-137 concentrations in West Greenland surface sea water collected in September 1987.



4.7. Summary of Radionuclide Determination in Greenland Sea Water Samples Collected in 1987

Figure 4.7 and Table 4.7 show the mean ^{90}Sr and ^{137}Cs concentrations in surface sea water collected in 5° latitude bands in the coastal waters around Greenland in 1987.

The figure shows that the input of ^{137}Cs as well as of ^{90}Sr comes in the Fram Strait in the northeast. In the case of ^{137}Cs, there are 3 sources to the enhanced levels in the northeastern Greenland waters: 1) global fallout in the Arctic Ocean, 2) discharges from Sellafield, which have reached these waters with the Norwegian and West Spitbergen Currents, and 3) fallout in the NE Atlantic from the Chernobyl accident. In the case of ^{90}Sr, the main source is global fallout. From observations in the East Greenland Current[2,4] made in earlier years, we may estimate the global fallout backgrounds in 1987. This is done by extrapolation of the exponential decreasing concentrations measured at Danmarkshavn, Angmagssalik and Prins Christians Sund (cf. Fig. 3.1). In the Arctic water (from the East Greenland Current) we estimate 3.9 Bq ^{137}Cs m^{-3} and 3.3 Bq ^{90}Sr m^{-3}. In a similar way, we may estimate the background levels in the NE Atlantic Ocean from Faroese observations[1] as 2.5 Bq ^{137}Cs m^{-3} and 1.75 Bq ^{90}Sr m^{-3}. From Fig. 4.7 it appears that the ^{137}Cs and ^{90}Sr concentrations observed along the west coast of Greenland are between the above estimates for Arctic and Atlantic water.

Table 4.7. Strontium-90 and cesium-137 mean concentrations in surface sea water with salinities ≥ 30‰ in 5° latitude bands collected around Greenland in 1987

	Bq m^{-3} ± 1 S.D. (N) west of 0°					
	West Greenland			East Greenland		
Latitude band	^{90}Sr	^{137}Cs	$^{137}Cs/^{90}Sr$	^{90}Sr	^{137}Cs	$^{137}Cs/^{90}Sr$
60-65	2.8 ± 0.29 (3)	4.7 ± 0.07 (2)	1.68 ± 0.18	1.64 (1)	12.6 (1)	
65-70	2.3 ± 0.22(18)	4.2 ± 0.43(18)	1.83 ± 0.26	2.6 ± 0.97 (8)	5.5 ± 1.76 (8)	2.12 ± 1.04
70-75	2.2 ± 0.35 (8)	3.3 ± 0.47 (8)	1.50 ± 0.32	3.0 ± 1.14(17)	7.2 ± 1.17(17)	2.40 ± 0.99
75-80	2.5 ± 0.14 (2)	3.0 ± 0.21 (2)	1.20 ± 0.11	3.9 ± 0.65 (9)	8.7 ± 1.32(10)	2.23 ± 0.50

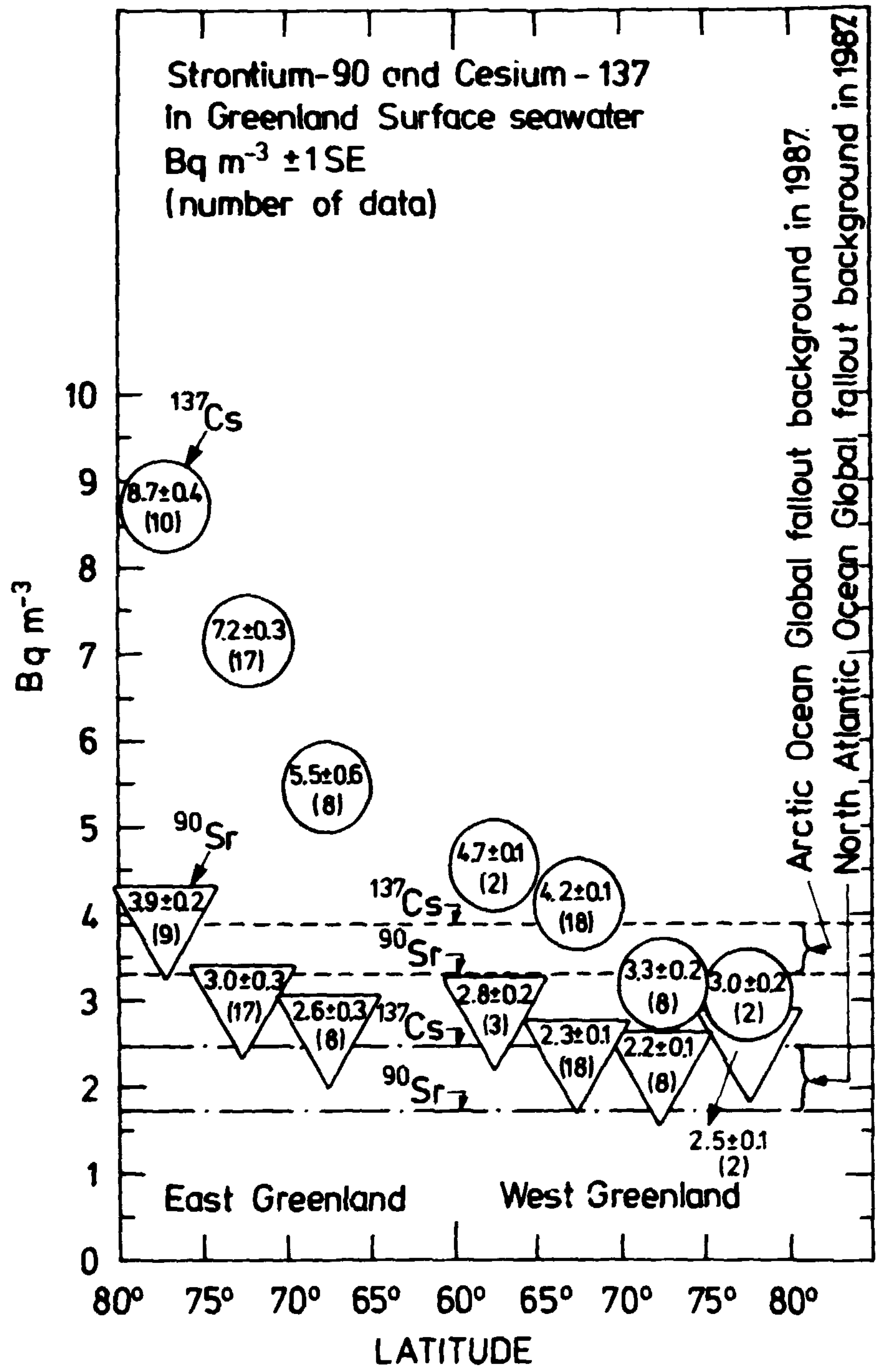


Fig. 4.7. Strontium-90 and cesium-137 in Greenland surface sea water (Unit: Bq m^{-3} ±1 S.E. (n)). All data are west of 0°, and salinities below 30‰ are excluded.

4.8. Radionuclides in Lichen Collected at a Norwegian Location 1985-1988

Every summer since 1985 lichen samples (Cladonia stellaris) have been collected 30 km southeast of Alvdal at Belling (62°02'N, 10°48'E) in Norway. The sampling site is an open plateau covered with a thick carpet of lichen. Table 4.8 shows the results. The ratios of other radionuclides relative to ^{137}Cs were all decay corrected to April 26, 1986, when the Chernobyl accident began. It appears that ^{106}Ru and ^{110m}Ag shows a shorter biological half-life in the lichen carpet than ^{137}Cs. It is also evident that the ^{137}Cs levels in the lichen from this location were vary variable. The effective half-life of ^{137}Cs in the lichen carpet (Bq m^{-2}) was 3 years. The effective half-life of the decay-corrected $^{106}Ru/^{137}Cs$ was 2.5 years, and for $^{110m}Ag/^{137}Cs$ we found 7.5 years.

Table 4.8. Radionuclides in Norwegian lichen collected 1985-1988 at 62°02'N 10°48'E

Year & date	Bq ^{137}Cs kg^{-1}	Bq ^{137}Cs m^{-2}	g K kg^{-1}	Bq ^{137}Cs $(kg\ K)^{-1}$	$^{134}Cs/^{137}Cs$	$^{60}Co/^{137}Cs$	$^{95}Zr/^{137}Cs$	$^{103}Ru/^{137}Cs$	$^{106}Ru/^{137}Cs$	$^{110m}Ag/^{137}Cs$	$^{125}Sb/^{137}Cs$	$^{144}Ce/^{137}Cs$
					at 26 April 1986							
20 Aug 1985	80	160	10.7	7.5	-	-	-	-	-	-	-	-
20 July 1986	5500	5200	-	-	0.57	0.0002 B	0.073	0.28	0.077	0.0112	-	0.063
21 Aug 1987	1810	4400	0.60	3000	0.58	0.00152	-	-	0.069	0.0108	-	0.054
24 Aug 1988	4000	2500	1.34	3000	0.59	0.00046	-	-	0.055	0.0094	-	-
24 Aug 1988	5800	3200	1.31	4400	0.59	0.00035	-	-	0.045 A	0.0091	-	-
8 July 1986*	3600	3900	2.63	1370	0.58	0.0002 B	0.03 B	0.38	0.100	0.0101	0.0121	-

*Collected at Valdres Aila (~61°N, ~9°E)

4.9. Thule Sediments Collected in 1984

Tables 4.9.1-4.9.39 show the results of Pu, Am and ^{137}Cs determinations of Thule sediments collected in August 1984. Some of the results have been reported earlier (Risø-R-528[4]).

The collection of sediment samples always imply a risk of transferring contaminated material to uncontaminated deeper sediment layers. In order to overcome this, two box core samples were collected and horizontal samples were taken after having carefully shaved the sides of the box sample. Table 4.2.39 shows analysis of two such "clean" samples. The layers sampled were about 25 cm and we would expect them to be free of accident Pu. This was apparently the case. The first sample was from location S4, 3.07 km from the point of impact (cf. Table 4.2.8). The $^{239,240}Pu$ deposition at this station (down to 15 cm) was 5400 Bq m^{-2} and already in the 12-15 cm depth the accident Pu had disappeared. The 25-30 cm layer contained 0.0114 Bq $^{239,240}Pu$ kg^{-1} and the mean level was significantly different from zero. This concentration was 30 times lower than found in the 12-15 cm layer. The ^{241}Am mean concentration in the 25-30 cm layer did not differ from zero activity. We conclude that there probably was a little global fallout Pu present in the 25-30 cm layer but no accident Pu.

The other sample was collected at the point of impact, where the total deposit down to 15 cm has been measured to 102 000 Bq $^{239,240}Pu$ m^{-2} (Table

4.2.1). The mean ^{239,240}Pu concentration in the 22-25 cm layer was 0.026 Bq kg $^{-1}$, this level was not significantly different from zero. The ^{241}Am mean concentration was 0.0085, and this level was probably significantly greater than zero activity. The ratio: ^{241}Am/^{239,240}Pu suggests that, if any Pu was present in this layer, it came from global fallout. Bioturbation had thus not been able to transfer accident Pu down to 25 cm in 16 years.

Fig. 4.9. Sampling locations at Thule in August 1984.

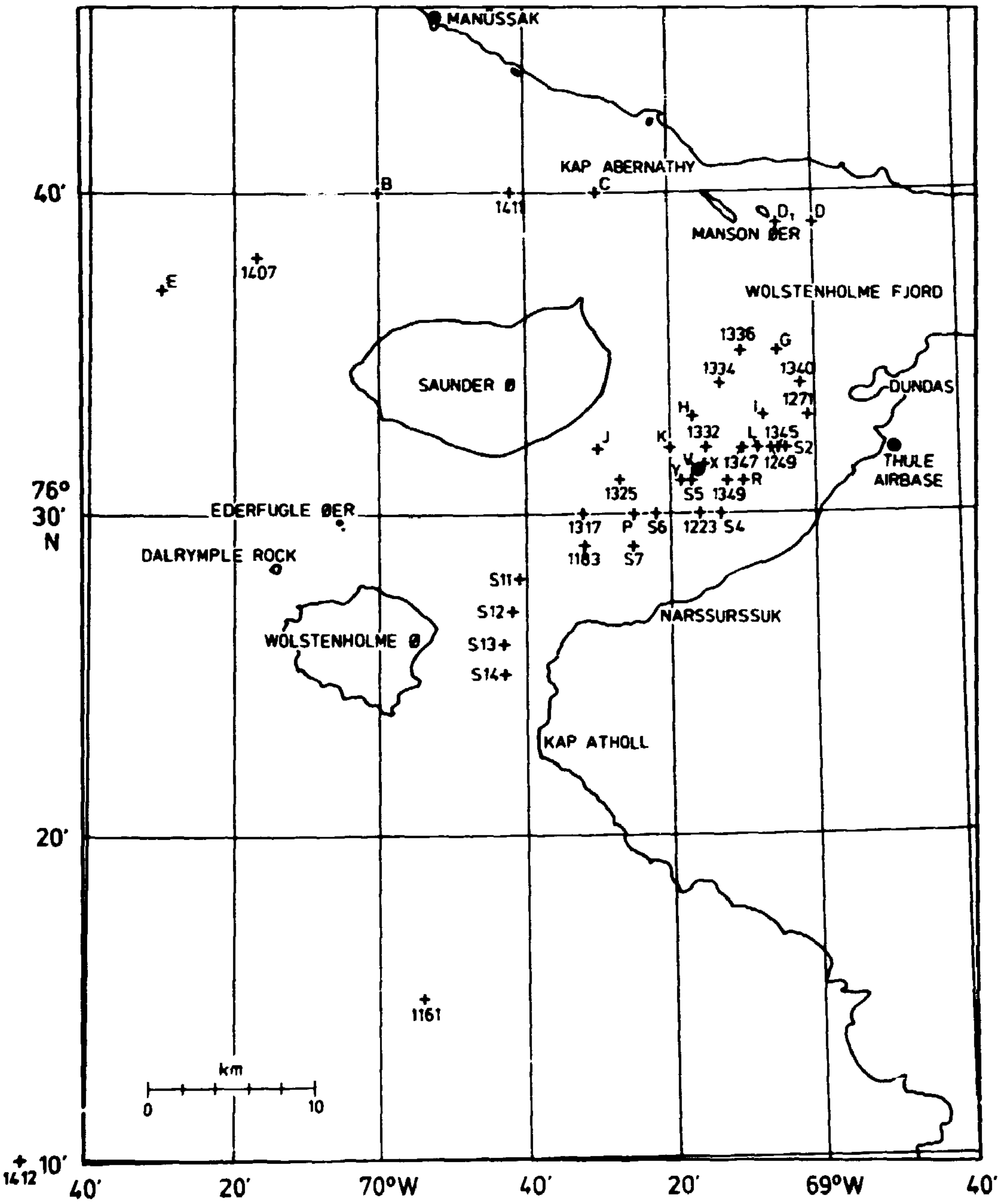


Table 4.9.1. Radionuclides in sediments collected with a 145 cm² corer at Thule in August 1984. Location V (1386) (cf. Fig. 4.2) 76°31'3 N 69°17'4 W. Depth 185 m. Distance from point of impact: 0 km

Depth in cm	$^{239,240}Pu$ Bq kg^{-1}	$^{239,240}Pu$ Bq m^{-2}	^{137}Cs Bq kg^{-1}	^{137}Cs Bq m^{-2}	^{241}Am Bq m^{-2}	$\frac{^{239,240}Pu}{^{137}Cs}$	$\frac{^{241}Am}{^{239,240}Pu}$	$\frac{^{238}Pu}{^{239,240}Pu}$	Total g
0-3	470	5600	9.1	108	760	52	0.136	0.016	172
3-6	1280	25300	8.9	177	2200	144	0.087	0.012	287
6-9	540	12700	9.2	215	1380	59	0.109	0.012	338
9-12	450	12300	8.1	223	1250	56	0.102	0.012	400
12-15	1500	45600	5.4	164	3700	280	0.081	0.011	442
Σ		102000		887	9300				

Table 4.9.2. Radionuclides in sediments collected with a 145 cm² corer at Thule in August 1984. Location S5 (1375) (cf. Fig. 4.2) 76°31' N 69°17' W. Depth 235 m. Distance from point of impact: 0.58 km

Depth in cm	$^{239,240}Pu$ Bq kg^{-1}	$^{239,240}Pu$ Bq m^{-2}	^{137}Cs Bq kg^{-1}	^{137}Cs Bq m^{-2}	^{241}Am Bq m^{-2}	$\frac{^{239,240}Pu}{^{137}Cs}$	$\frac{^{241}Am}{^{239,240}Pu}$	$\frac{^{238}Pu}{^{239,240}Pu}$	Total g
0-3	280	2900	12.6	130	240	22	0.083	0.010	150
3-6	200	3600	13.8	247	490	14.5	0.135	0.016	260
6-9	60	1670	7.8	152	136	7.7	0.081	0.014	281
9-12	19.6	400	2.8	58	49	7.0	0.123	-	295
12-15	40	900	1.12	25	210	36	0.23	0.016	325
15-18	8.5	159	-	-	17.1	-	0.108	-	273
Σ		9600		612	1140				

Table 4.9.3. Radionuclides in sediments collected with a 145 cm² corer at Thule in August 1984. Location Y (1382) (cf. Fig. 4.2) 76°31' N 69°18'5 W. Depth 200 m Distance from point of impact: 0.73 km

Depth in cm	$^{239,240}Pu$ Bq kg^{-1}	$^{239,240}Pu$ Bq m^{-2}	^{137}Cs Bq kg^{-1}	^{137}Cs Bq m^{-2}	^{241}Am Bq m^{-2}	$\frac{^{239,240}Pu}{^{137}Cs}$	$\frac{^{241}Am}{^{239,240}Pu}$	$\frac{^{238}Pu}{^{239,240}Pu}$	Total g
0-3	67	430	9.7	62	46	6.9	0.11	0.016 A	92
3-6	88	1590	12.6	226	182	7.0	0.11	0.015	261
6-9	24	530	6.0	132	65	4.0	0.12	0.011	320
9-12	3.6	72	3.0	62	11.0	1.2	0.15	0.05 B	296
12-15	0.55	14	1.08	27	2.1	0.51	0.15	-	369
15-18	0.13	3.6	-	-	4.5 A	-	1.26 A	-	404
Σ		2600		534	310				

Table 4.9.4. Radionuclides in sediments collected with a 145 cm² corer at Thule in August 1984. Location X (1378) (cf. Fig. 4.2) 76°31' N 69°15' W. Depth 195 m. Distance from point of impact: 0.98 km

Depth in cm	$^{239,240}Pu$ Bq kg^{-1}	$^{239,240}Pu$ Bq m^{-2}	^{137}Cs Bq kg^{-1}	^{137}Cs Bq m^{-2}	^{241}Am Bq m^{-2}	$\frac{^{239,240}Pu}{^{137}Cs}$	$\frac{^{241}Am}{^{239,240}Pu}$	$\frac{^{238}Pu}{^{239,240}Pu}$	Total g
0-3	182	2090	6.2	71	260	29	0.12	0.015	166
3-6	370	6400	7.3	126	710	51	0.11	0.011	253
6-9	2800	66000	8.4	198	4800	330	0.073	0.008	343
9-12	530	13600	6.8	177	1490	78	0.11	0.013	374
12-15	183	2200	6.9	83	280	27	0.13	0.012	175
Σ		90000		655	7540				

Table 4.9.5. Radionuclides in sediments collected with a 145 cm² corer at Thule in August 1984. Location 1332 (between H and X) (cf. Fig. 4.2) 76°32' N 69°15' W. Depth 182 m. Distance from point of impact: 1.66 km

Depth in cm	$^{239,240}Pu$ Bq kg^{-1}	$^{239,240}Pu$ Bq m^{-2}	^{137}Cs Bq kg^{-1}	^{137}Cs Bq m^{-2}	^{241}Am Bq m^{-2}	$\frac{^{239,240}Pu}{^{137}Cs}$	$\frac{^{241}Am}{^{239,240}Pu}$	$\frac{^{238}Pu}{^{239,240}Pu}$	Total g
0-3	129	1260	6.2	60	151	21	0.120	0.015	141
3-6	640	13100	6.5	132	1590	98	0.121	0.013	294
6-9	420	8100	7.9	152	1000	53	0.123	0.015	280
9-12	163	3300	9.3	188	320	17.5	0.097	0.014	295
12-15	1260	35000	6.3	174	5100	200	0.146	0.017	400
Σ		61000		706	8200				

Table 4.9.6.1. Radionuclides in sediments collected with a 145 cm² corer at Thule in August 1984. Location K (1328) (cf. Fig. 4.2) 76°32' N 69°20' W. Depth 173 m. Distance from point of impact: 1.72 km

Depth in cm	$^{239,240}Pu$ Bq kg^{-1}	$^{239,240}Pu$ Bq m^{-2}	^{137}Cs Bq kg^{-1}	^{137}Cs Bq m^{-2}	^{241}Am Bq m^{-2}	$\frac{^{239,240}Pu}{^{137}Cs}$	$\frac{^{241}Am}{^{239,240}Pu}$	$\frac{^{238}Pu}{^{239,240}Pu}$	Total g
0-3	39	230	4.1	24	29/27	9.5	0.13/0.117	0.016	84
3-6	12.1	280	2.9	66	155/35	4.2	0.55/0.125	-	332
6-9.5	25	560	5.1	114	220/55	4.9	0.40/0.098	0.010 A	322
Σ		1060		203	400/117				

Table 4.9.6.2. Radionuclides in sediments collected with a 145 cm² corer at Thule in August 1984. Location K (1327) (cf. Fig. 4.2) 76°32' N 69°20' W. Depth 173 m. Distance from point of impact: 1.72 km

Depth in cm	$^{239,240}Pu$ Bq kg^{-1}	$^{239,240}Pu$ Bq m^{-2}	^{137}Cs Bq kg^{-1}	^{137}Cs Bq m^{-2}	^{241}Am Bq m^{-2}	$\frac{^{239,240}Pu}{^{137}Cs}$	$\frac{^{241}Am}{^{239,240}Pu}$	$\frac{^{238}Pu}{^{239,240}Pu}$	Total g
0-3	42	510	4.2	51		10.0		0.019 A	177
3-6	54	1340	2.9	72		18.6		0.015 B	363
6-9	74	1830	1.22	30		61		0.013 B	355
9-12	3.6	79	0.87	19	8.7	4.1	0.11	0.027 B	320
Σ		3800		172					

Table 4.9.7. Radionuclides in sediments collected with a 145 cm^2 corer at Thule in August 1984. Location 1223 (S-E of S5) (cf. Fig. 4.2) 76°30' N 69°16' W. Depth 186 m. Distance from point of impact: 2.48 km

Depth	^{239,240}Pu		^{137}Cs		^{241}Am	^{239,240}Pu / ^{137}Cs	^{241}Am / ^{239,240}Pu	^{238}Pu / ^{239,240}Pu	Total
in cm	Bq kg^{-1}	Bq m^{-2}	Bq kg^{-1}	Bq m^{-2}	Bq m^{-2}				g
0-3	46	480	7.1	73	73	6.5	0.152	0.018	150
3-6	16.1	320	3.7	75	40	4.4	0.125	0.023 A	293
6-9	34	850	4.0	100	103	8.5	0.121	0.013 A	364
9-12	26	660	6.0	152	71	4.3	0.108	0.015	366
12-15	75	2300	7.4	222	290	10.1	0.126	0.018	438
Σ		4600		622	580				

Table 4.9.8. Radionuclides in sediments collected with a 145 cm^2 corer at Thule in August 1984. Location S4 (1230) (cf. Fig. 4.2) 76°30' N 69°13' W. Depth 245 m. Distance from point of impact: 3.07 km

Depth	^{239,240}Pu		^{137}Cs		^{241}Am	^{239,240}Pu / ^{137}Cs	^{241}Am / ^{239,240}Pu	^{238}Pu / ^{239,240}Pu	Total
in cm	Bq kg^{-1}	Bq m^{-2}	Bq kg^{-1}	Bq m^{-2}	Bq m^{-2}				g
0-3	46	390	12.7	106		3.6		0.018	122
3-6	250	4800	18.5	350	620	13.5	0.129	0.015	275
6-9	8.5	157	8.3	153	24	1.02	0.153	0.016 B	266
9-12	1.17	23	1.92	37	6.5	0.61	0.283	-	282
12-15	0.35	6.5	1.03	19.3	-	0.34	-	-	272
Σ		5400		666					

Table 4.9.9. Radionuclides in sediments collected with a 145 cm^2 corer at Thule in August 1984. Location S6 (1215) (cf. Fig. 4.2) 76°30' N 69°22' W. Depth 250 m. Distance from point of impact: 3.12 km

Depth	^{239,240}Pu		^{137}Cs		^{241}Am	^{239,240}Pu / ^{137}Cs	^{241}Am / ^{239,240}Pu	^{238}Pu / ^{239,240}Pu	Total
in cm	Bq kg^{-1}	Bq m^{-2}	Bq kg^{-1}	Bq m^{-2}	Bq m^{-2}				g
0-3	64	640	11.1	111	86	5.8	0.134	0.015	146
3-6	83	1310	12.5	198	167	6.6	0.127	0.016	230
6-9	13.6	285	6.9	145	32	2.0	0.112	0.028	304
9-12	3.9	94	1.71	41	-	2.3	-	0.028	349
12-15	4.1	90	<1	-		-		-	314
15-18	7.9	98	0.75	9.3	12.3	10.5	0.126	0.022	180
Σ		2500		505	300				

Table 4.9.10. Radionuclides in sediments collected with a 145 cm² corer at Thule in August 1984. Location H (1300) (cf. Fig. 4.2) 76°33' N 69°17' W. Depth 195 m. Distance from point of impact: 3.15 km

Depth	$^{239,240}Pu$		^{137}Cs		^{241}Am	$^{239,240}Pu$ / ^{137}Cs	^{241}Am / $^{239,240}Pu$	^{238}Pu / $^{239,240}Pu$	Total
in cm	Bq kg^{-1}	Bq m^{-2}	Bq kg^{-1}	Bq m^{-2}	Bq m^{-2}				g
0-3	140	1080	11.7	90	116	12.0	0.11	0.013	111
3-6	290	4800	11.4	185	540	25	0.11	0.013	236
6-9	96	1840	8.7	166	250	11.0	0.14	0.015	277
9-12	65	1240	6.8	130	143	9.6	0.12	0.011 A	278
12-15	86	1840	5.6	119	250	15.4	0.14	0.017	310
15-18	99	1240	3.9	48	153	25	0.12	0.015	181
Σ		12000		738	1450				

Table 4.9.11. Radionuclides in sediments collected with a 145 cm² corer at Thule in August 1984. Location R (1240) (cf. Fig. 4.2) 76°31' N 69°10' W. Depth 240 m. Distance from point of impact: 3.24 km

Depth	$^{239,240}Pu$		^{137}Cs		^{241}Am	$^{239,240}Pu$ / ^{137}Cs	^{241}Am / $^{239,240}Pu$	^{238}Pu / $^{239,240}Pu$	Total
in cm	Bq kg^{-1}	Bq m^{-2}	Bq kg^{-1}	Bq m^{-2}	Bq m^{-2}				g
0-3	49	570	13.0	149	62	3.8	0.108	0.012	166
3-6	113*	1890*	17.5	290	220	6.5	0.116	0.014*	241
6-9	20	380	19.2	360	44	1.04	0.115	0.025	272
9-12	6.6	129	7.9	154	23 B	0.84	0.178	0.010	283
12-15	0.4	6.8	2.2	36	-	0.18	-	-	242
Σ		3000		989	350				
*Double determinations									
	5400*	90000*				5100*		0.008*	

Table 4.9.12. Radionuclides in sediments collected with a 145 cm² corer at Thule in August 1984. Location L (1256) (cf. Fig. 4.2) 76°32' N 69°10' W. Depth 140 m. Distance from point of impact: 3.45 km

Depth	$^{239,240}Pu$		^{137}Cs		^{241}Am	$^{239,240}Pu$ / ^{137}Cs	^{241}Am / $^{239,240}Pu$	^{238}Pu / $^{239,240}Pu$	Total
in cm	Bq kg^{-1}	Bq m^{-2}	Bq kg^{-1}	Bq m^{-2}	Bq m^{-2}				g
0-3	56	880	5.0	80	90	11.2	0.102	0.015	230
3-6	48	1070	5.9	130	114	8.1	0.107	0.008	320
6-9	12.6	280	4.2	94	42	3.0	0.150	0.018	326
9-12	3.6	67	1.07	20	13.2 A	3.4	0.197 A	0.022	269
12-15	0.41	6.8	-	-		-		-	240
Σ		2300		324	260				

Table 4.9.13. Radionuclides in sediments collected with a 145 cm^2 corer at Thule in August 1984. Location P (1204) (cf. Fig. 4.2) 76°30' N 69°25' W. Depth 260 m. Distance from point of impact: 4.07 km

Depth	$^{239,240}Pu$		^{137}Cs		^{241}Am	$^{239,240}Pu/^{137}Cs$	$^{241}Am/^{239,240}Pu$	$^{238}Pu/^{239,240}Pu$	Total
in cm	Bq kg^{-1}	Bq m^{-2}	Bq kg^{-1}	Bq m^{-2}	Bq m^{-2}				g
0-3	152	2100	10.1	137	220	15.1	0.105	0.014	196
3-6	117	2300	14.0	280	290	8.4	0.126	0.015	287
6-9	17.5	360	10.0	210	59	1.75	0.164	0.015	299
9-12	5.1	112	3.8	82	17.8	1.34	0.159	0.067	316
12-15	1.27	28	0.94	21	12.8	1.35	0.457		326
Σ		4900		730	600				

Table 4.9.14. Radionuclides in sediments collected with a 145 cm^2 corer at Thule in August 1984. Location 1325 (cf. Fig. 4.2) 76°31' N 69°27' W. Depth 150 m. Distance from point of impact: 4.18 km

Depth	$^{239,240}Pu$		^{137}Cs		^{241}Am	$^{239,240}Pu/^{137}Cs$	$^{241}Am/^{239,240}Pu$	$^{238}Pu/^{239,240}Pu$	Total
in cm	Bq kg^{-1}	Bq m^{-2}	Bq kg^{-1}	Bq m^{-2}	Bq m^{-2}				g
0-3	24	380	4.0	63	37	6.0	0.097	0.023	230
3-6	54	1160	4.2	88	134	12.9	0.116	0.017	308
6-9	30	900	4.4	128	90	6.8	0.099	0.012	428
9-12			2.4	68					411
Σ		2440		347	261				

Table 4.9.15. Radionuclides in sediments collected with a 145 cm^2 corer at Thule in August 1984. Location 1347 (S-E of L) (cf. Fig. 4.2) 76°32' N 69°08' W. Depth 215 m. Distance from point of impact: 4.26 km

Depth	$^{239,240}Pu$		^{137}Cs		^{241}Am	$^{239,240}Pu/^{137}Cs$	$^{241}Am/^{239,240}Pu$	$^{238}Pu/^{239,240}Pu$	Total
in cm	Bq kg^{-1}	Bq m^{-2}	Bq kg^{-1}	Bq m^{-2}	Bq m^{-2}				g
0-3	47	390	14.0	117		3.4		0.015	122
3-6	84	1330	16.0	260		5.3		0.015	231
6-9	18.2	300	13.6	230		1.34		0.016	241
9-12	1.55	29	5.2	96	7.5	0.30	0.26	-	271
12-15	0.23	3.7	-	-	-	-		-	231
15-16	2.3	13	-	-	1.7	-	0.13	-	84
Σ		2070		700					

Table 4.9.16. Radionuclides in sediments collected with a 145 cm² corer at Thule in August 1984. Location 1249 (cf. Fig. 4.2) 76°32' N 69°06' W. Depth 240 m. Distance from point of impact: 5.09 km

Depth in cm	$^{239,240}Pu$ Bq kg^{-1}	$^{239,240}Pu$ Bq m^{-2}	^{137}Cs Bq kg^{-1}	^{137}Cs Bq m^{-2}	^{241}Am Bq m^{-2}	$^{239,240}Pu$ / ^{137}Cs	^{241}Am / $^{239,240}Pu$	^{238}Pu / $^{239,240}Pu$	Total g
0-3	112	1000	13.5	120	90	8.3	0.090	0.012	130
3-6	570	9200	14.7	240	640	39	0.070	0.010	235
6-9	15.7	290	6.5	121	34	2.4	0.117	0.030	268
9-12	31	600	2.2	43	45	14.1	0.075	0.013	283
12-15	2.7	52	1.52	30	5.9	1.8	0.113	-	281
15-18	0.25	4	-	-	-	-	-	-	219
Σ		11100		550	810				

Table 4.9.17. Radionuclides in sediments collected with a 145 cm² corer at Thule in August 1984. Location 1334 (cf. Fig. 4.2) 76°34' N 69°13' W. Depth 200 m. Distance from point of impact: 5.35 km

Depth in cm	$^{239,240}Pu$ Bq kg^{-1}	$^{239,240}Pu$ Bq m^{-2}	^{137}Cs Bq kg^{-1}	^{137}Cs Bq m^{-2}	^{241}Am Bq m^{-2}	$^{239,240}Pu$ / ^{137}Cs	^{241}Am / $^{239,240}Pu$	^{238}Pu / $^{239,240}Pu$	Total g
0-3	280	2400	13.1	113	310	21.4	0.13	0.017	125
3-6	250	3700	14.2	210	270	17.6	0.07	0.014	215
6-9	106	1850	14.0	240	200	7.6	0.11	0.014	253
9-12	240	4300	9.1	161	480	26	0.11	0.013	255
12-15	65	1260	4.1	79	191	15.9	0.15	0.013	281
15-18	2.8	30	1.8	19.5	6.9 A	1.56	0.23 A	0.036	157
18-21	1.81	37	2.5	22	5.4	0.72	0.15		296
Σ		13600		845	1460				

Table 4.9.18. Radionuclides in sediments collected with a 145 cm² corer at Thule in August 1984. Location S7 (1194) (cf. Fig. 4.2) 76°29' N 69°25' W. Depth 280 m. Distance from point of impact: 5.38 km

Depth in cm	$^{239,240}Pu$ Bq kg^{-1}	$^{239,240}Pu$ Bq m^{-2}	^{137}Cs Bq kg^{-1}	^{137}Cs Bq m^{-2}	^{241}Am Bq m^{-2}	$^{239,240}Pu$ / ^{137}Cs	^{241}Am / $^{239,240}Pu$	^{238}Pu / $^{239,240}Pu$	Total g
0-3	37	470	8.8	112	53	4.2	0.113	0.019	185
3-6	66	1570	9.0	210	186	7.3	0.118	0.017	344
6-9	17.1	330	3.8	74	45	4.5	0.136	0.016	282
9-12	25	500	-	-	111	-	0.222	0.016	292
12-15	1.28	24	-	-	-	-	-	-	275
Σ		2900		400	400				

Table 4.9.19. Radionuclides in sediments collected with a 145 cm² corer at Thule in August 1984. Location I (1288) (cf. Fig. 4.2) 76°33' N 69°07' W. Depth 160 m. Distance from point of impact: 5.48 km

Depth in cm	$^{239,240}Pu$ Bq kg^{-1}	$^{239,240}Pu$ Bq m^{-2}	^{137}Cs Bq kg^{-1}	^{137}Cs Bq m^{-2}	^{241}Am Bq m^{-2}	$^{239,240}Pu$/^{137}Cs	^{241}Am/$^{239,240}Pu$	^{238}Pu/$^{239,240}Pu$	Total g
0-3	55	550	10.3	103	64	5.3	0.116	0.017	145
3-6	13.2	280	5.8	121		2.3		-	303
6-9	2.8	71	1.72	44		1.62		0.014	369
9-12	0.47	11.2	-	-	-	-	-	-	364
Σ		910		270					

Table 4.9.20. Radionuclides in sediments collected with a 145 cm² corer at Thule in August 1984. Location: south of J (cf. Fig. 4.2) (1325). Position: 76°31' N 69°27' W. Depth 150 m. Distance from point of impact: 4.2 km

Depth in cm	$^{239,240}Pu$ Bq kg^{-1}	$^{239,240}Pu$ Bq m^{-2}	^{137}Cs Bq kg^{-1}	^{137}Cs Bq m^{-2}	^{241}Am Bq m^{-2}	$^{239,240}Pu$/^{137}Cs	^{241}Am/$^{239,240}Pu$	^{238}Pu/$^{239,240}Pu$	Total g
0-3	23.9	380	4.0	63	37	5.98	0.097	0.023	230
3-6	54.5	1160	4.2	88	134	12.98	0.116	0.017	308
6-9	30.4	900	4.4	128	90	6.91	0.099	0.012	428
9-12	-	-	2.4	68	-	-	-	-	411
Σ		2440		347	261				

Table 4.9.21. Radionuclides in sediments collected with a 145 cm² corer at Thule in August 1984. Location: north of S2 (cf. Fig. 4.2) (1345). Position: 76°32' N 69°05' W. Depth 220 m. Distance from point of impact: 5.5 km

Depth in cm	$^{239,240}Pu$ Bq kg^{-1}	$^{239,240}Pu$ Bq m^{-2}	^{137}Cs Bq kg^{-1}	^{137}Cs Bq m^{-2}	^{241}Am Bq m^{-2}	$^{239,240}Pu$/^{137}Cs	^{241}Am/$^{239,240}Pu$	^{238}Pu/$^{239,240}Pu$	Total g
0-3	60	370	13.4	82	37	4.5	0.101	0.014	89
3-6	61	880	15.8	225	104	3.9	0.119	0.015	207
6-9	56	940	17.2	285	118	3.3	0.126	0.014	241
9-12	40	660	13.4	220	79	3.0	0.120	0.015	239
12-15	4.1	82	4.9	96	13.4	0.84	0.163	0.028	286
15-18	1.69	33	1.0	20	7.7	1.69	0.23	-	288
18-20	3.7	40	3.3	35	5.9	1.12	0.148	-	155
Σ		3000		963	370				

Table 4.9.22. Radionuclides in sediments collected with a 145 cm² corer at Thule in August 1984. Location: J (cf. Fig. 4.2) (1305). Position: 76°32' N 69°30' W. Depth 100 m. Distance from point of impact: 5.6 km

Depth	$^{239,240}Pu$		^{137}Cs		^{241}Am	$^{239,240}Pu$ / ^{137}Cs	^{241}Am / $^{239,240}Pu$	^{238}Pu / $^{239,240}Pu$	Total
in cm	Bq kg^{-1}	Bq m^{-2}	Bq kg^{-1}	Bq m^{-2}	Bq m^{-2}				g
0-3	12.9	300	4.5	105	32	2.87	0.107	0.011	336
3-6	24.8	800	3.6	115	68	6.89	0.085	0.026	468
6-9	3.4	124	1.5	56	14.6	2.27	0.118	0.041	523
Σ		1224		276	115				

Table 4.9.23. Radionuclides in sediments collected with a 145 cm² corer at Thule in August 1984. Location: between O & P (cf. Fig. 4.2) (1317). Position: 76°30' N 69°32' W. Depth 176 m. Distance from point of impact: 6.8 km

Depth	$^{239,240}Pu$		^{137}Cs		^{241}Am	$^{239,240}Pu$ / ^{137}Cs	^{241}Am / $^{239,240}Pu$	^{238}Pu / $^{239,240}Pu$	Total
in cm	Bq kg^{-1}	Bq m^{-2}	Bq kg^{-1}	Bq m^{-2}	Bq m^{-2}				g
0-3	32.0	105	8.8	29	10	3.64	0.090	0.012	48
3-6	15.1	306	4.5	91	31	3.36	0.100	0.013	295
6-9	4.3	144	1.3	44	18	3.30	0.126	0.027	487
9-12	-	-	1.2	27	-	-	-	-	339
Σ		555		191	59				

Table 4.9.24. Radionuclides in sediments collected with a 145 cm² corer at Thule in August 1984. Location: west of G (cf. Fig. 4.2) (1336). Position: 76°35' N 69°10' W. Depth 190 m. Distance from point of impact: 7.6 km

Depth	$^{239,240}Pu$		^{137}Cs		^{241}Am	$^{239,240}Pu$ / ^{137}Cs	^{241}Am / $^{239,240}Pu$	^{238}Pu / $^{239,240}Pu$	Total
in cm	Bq kg^{-1}	Bq m^{-2}	Bq kg^{-1}	Bq m^{-2}	Bq m^{-2}				g
0-3	116	900	11.9	92	87	9.7	0.097	0.015	112
3-6	114	2060	12.7	228	240	9.0	0.118	0.016	261
6-9	40	725	9.2	167	93	4.3	0.129	0.017	264
9-12	25	475	5.8	111	50	4.3	0.106	0.014	274
12-15	106	2100	3.8	73	260	28	0.122	0.018	285
15-18	10	210	2.7	56	26	3.7	0.123	0.012	299
Σ		6500		727	760				

Table 4.9.25. Radionuclides in sediments collected with a 145 cm^2 corer at Thule in August 1984. Location: north of S9 (cf. Fig. 4.2) (1183). Position: 76°29' N 69°32' W. Depth 244 m. Distance from point of impact: 7.6 km

Depth	$^{239,240}Pu$		^{137}Cs		^{241}Am	$^{239,240}Pu$ / ^{137}Cs	^{241}Am / $^{239,240}Pu$	^{238}Pu / $^{239,240}Pu$	Total
in cm	Bq kg^{-1}	Bq m^{-2}	Bq kg^{-1}	Bq m^{-2}	Bq m^{-2}				g
0-3	36	670	9.4	177		3.86		0.015	275
3-6	51 ± 7	1210 ± 160	9.2	217	165	5.5	0.136	0.016	341
6-9	3.2	95	2.0	60		1.62		0.012	424
9-12	0.73	19	< 1	< 30		< 0.73		0.043	384
Σ		1990		~480					

Table 4.9.26. Radionuclides in sediments collected with a 145 cm^2 corer at Thule in August 1984. Location: south of S1 (cf. Fig. 4.2) (1271). Position: 76°33' N 69°01' W. Depth 227 m. Distance from point of impact: 7.8 km

Depth	$^{239,240}Pu$		^{137}Cs		^{241}Am	$^{239,240}Pu$ / ^{137}Cs	^{241}Am / $^{239,240}Pu$	^{238}Pu / $^{239,240}Pu$	Total
in cm	Bq kg^{-1}	Bq m^{-2}	Bq kg^{-1}	Bq m^{-2}	Bq m^{-2}				g
0-3	58	460	14.2	112	44	4.1	0.095	0.015	115
3-6	51	890	17.3	298	111	2.9	0.124	0.013	251
6-9	38	700	20.6	381	81	1.85	0.115	0.018	268
9-12	19.8	350	15.7	274	35	1.26	0.101	0.012	253
12-15	2.6	45	4.9	83	7.2	0.53	0.16	0.021	248
Σ		2400		1148	280				

Table 4.9.27. Radionuclides in sediments collected with a 145 cm^2 corer at Thule in August 1984. Location: between G&S1 (cf. Fig. 4.2) (1340). Position: 76°34' N 69°02' W. Depth 168 m. Distance from point of impact: 8.3 km

Depth	$^{239,240}Pu$		^{137}Cs		^{241}Am	$^{239,240}Pu$ / ^{137}Cs	^{241}Am / $^{239,240}Pu$	^{238}Pu / $^{239,240}Pu$	Total
in cm	Bq kg^{-1}	Bq m^{-2}	Bq kg^{-1}	Bq m^{-2}	Bq m^{-2}				g
0-3	43	530	11.7	146	57	3.6	0.107	0.017	181
3-6	5.5	88	5.7	92	12	0.96	0.136	0.011	234
6-9	1.43	25	1.45	25	3.6	1.00	0.146	-	252
9-12	0.70	6	1.44	12	0.93	0.50	0.160	-	120
Σ		650		275	74				

Table 4.9.28. Radionuclides in sediments collected with a 145 cm² corer at Thule in August 1984. Location: G (cf. Fig. 4.2) (1282). Position: 76°35' N 69°05' W. Depth 187 m. Distance from point of impact: 8.7 km

Depth in cm	$^{239,240}Pu$ Bq kg^{-1}	$^{239,240}Pu$ Bq m^{-2}	^{137}Cs Bq kg^{-1}	^{137}Cs Bq m^{-2}	^{241}Am Bq m^{-2}	$^{239,240}Pu$ / ^{137}Cs	^{241}Am / $^{239,240}Pu$	^{238}Pu / $^{239,240}Pu$	Total g
0-3	42	450	13.1	139	51	3.2	0.113	0.015	154
3-6	33	540	10.9	176	65	3.0	0.120	0.017	235
6-9	27	510	2.8	52	84	9.6	0.160	0.017	272
9-12	1.2	25	<0.9	<20	8.2	>1.3	0.33	-	303
12-15	0.15	4	<0.9	<25	-	>0.2	-	-	396
Σ		1530		<412	210				

Table 4.9.29. Radionuclides in sediments collected with a 145 cm² corer at Thule in August 1984. Location: S11 (cf. Fig. 4.2) (1181). Position: 76°28' N 69°41' W. Depth 285 m. Distance from point of impact: 11.9 km

Depth in cm	$^{239,240}Pu$ Bq kg^{-1}	$^{239,240}Pu$ Bq m^{-2}	^{137}Cs Bq kg^{-1}	^{137}Cs Bq m^{-2}	^{241}Am Bq m^{-2}	$^{239,240}Pu$ / ^{137}Cs	^{241}Am / $^{239,240}Pu$	^{238}Pu / $^{239,240}Pu$	Total g
0-3	5.6	23	4.2	46		1.34		0.033	159
3-6	5.7	163	4.5	127		1.27		0.016	414
6-9	6.8	183	4.7	128		1.53		0.017	393
Σ		370		301					

Table 4.9.30. Radionuclides in sediments collected with a 145 cm² corer at Thule in August 1984. Location: S12 (cf. Fig. 4.2) (1177). Position: 76°27' N 69°42' W. Depth 285 m. Distance from point of impact: 13.3 km

Depth in cm	$^{239,240}Pu$ Bq kg^{-1}	$^{239,240}Pu$ Bq m^{-2}	^{137}Cs Bq kg^{-1}	^{137}Cs Bq m^{-2}	^{241}Am Bq m^{-2}	$^{239,240}Pu$ / ^{137}Cs	^{241}Am / $^{239,240}Pu$	^{238}Pu / $^{239,240}Pu$	Total g
0-3	18.8	80	5.1	22		3.7		0.018	62
3-6	13.2	342	5.0	129		2.6		0.019	376
6-9	43	1540	5.2	182		8.4		0.011	513
Σ		1962		333					

Table 4.9.31. Radionuclides in sediments collected with a 145 cm² corer at Thule in August 1984. Location: S13 (cf. Fig. 4.2) (1170). Position: 76°26' N 69°43' W. Depth 300 m. Distance from point of impact: 14.8 km

Depth in cm	$^{239,240}Pu$ Bq kg^{-1}	$^{239,240}Pu$ Bq m^{-2}	^{137}Cs Bq kg^{-1}	^{137}Cs Bq m^{-2}	^{241}Am Bq m^{-2}	$^{239,240}Pu$ / ^{137}Cs	^{241}Am / $^{239,240}Pu$	^{238}Pu / $^{239,240}Pu$	Total g
0-3	20.4	180	5.2	46		3.9		0.019	128
3-6	4.3	149	3.8	131		1.13		0.030	504
6-9	4.0	82	4.2	86		0.95		0.025	296
Σ		411		263					

Table 4.9.32. Radionuclides in sediments collected with a 145 cm² corer at Thule in August 1984. Location D (cf. Fig. 4.2) (1402). Position: 76°39' N 69°00' W. Depth 85 m. Distance from point of impact: 16.1 km

Depth	$^{239,240}Pu$		^{137}Cs		^{241}Am	$^{239,240}Pu$ / ^{137}Cs	^{241}Am / $^{239,240}Pu$	^{238}Pu / $^{239,240}Pu$	Total
in cm	Bq kg⁻¹	Bq m⁻²	Bq kg⁻¹	Bq m⁻²	Bq m⁻²				g
0-3	3.8	62	3.0	49	6.1	1.27	0.099	0.018	240
3-6	0.25	5.4	1.7	36	1.7 B	0.15	0.31 B	-	308
6-9	0.22	5.1	0.7 B	16	-	0.3	-	-	330
9-12	0.14	12.5	0.9 B	27	-	0.15	-	-	455
12-15	0.36	11.7	1.0 B	32	1.8 A	0.4	0.15 A	-	467
15-18	0.091	3.8	0.4 B	17	-	0.2	-	-	604
Σ		100		178	10				

Table 4.9.33. Radionuclides in sediments collected with a 145 cm² corer at Thule in August 1984. Location: S 14 (cf. Fig. 4.2) (1169). Position: 76°25' N 69°43' W. Depth 250 m. Distance from point of impact: 16.1 km

Depth	$^{239,240}Pu$		^{137}Cs		^{241}Am	$^{239,240}Pu$ / ^{137}Cs	^{241}Am / $^{239,240}Pu$	^{238}Pu / $^{239,240}Pu$	Total
in cm	Bq kg⁻¹	Bq m⁻²	Bq kg⁻¹	Bq m⁻²	Bq m⁻²				g
0-3	12.8	142	5.5	61		2.33		0.007	161
3-6	2.5	75	2.3	70		1.09		0.042	435
6-9	1.62	38	1.4	33		1.16		-	343
Σ		255		164					

Table 4.9.34. Radionuclides in sediments collected with a 145 cm² corer at Thule in August 1984. Location: C (cf. Fig. 4.2) (1404). Position: 76°40' N 69°30' W. Depth 110 m. Distance from point of impact: 17.0 km

Depth	$^{239,240}Pu$		^{137}Cs		^{241}Am	$^{239,240}Pu$ / ^{137}Cs	^{241}Am / $^{239,240}Pu$	^{238}Pu / $^{239,240}Pu$	Total
in cm	Bq kg⁻¹	Bq m⁻²	Bq kg⁻¹	Bq m⁻²	Bq m⁻²				g
0-3	36	470	9.8	130	58	3.7	0.122	0.016	192
3-6	4.9	97	6.5	130	12.8	0.75	0.132	0.017	289
6-9	1.7	32	3.6	68	4.9	0.47	0.151	-	275
9-12	0.17	3	<0.9	< 18	-	>0.2	-	-	292
Σ		600		<346	76				

Table 4.9.35. Radionuclides in sediments collected with a 145 cm² corer at Thule in August 1984. Location: 1411 (cf. Fig. 4.2). Position: 76°40' N 69°42' W. Depth 60 m. Distance from point of impact: 19.3 km

Depth	$^{239,240}Pu$		^{137}Cs		^{241}Am	$^{239,240}Pu$ / ^{137}Cs	^{241}Am / $^{239,240}Pu$	^{238}Pu / $^{239,240}Pu$	Total
in cm	Bq kg⁻¹	Bq m⁻²	Bq kg⁻¹	Bq m⁻²	Bq m⁻²				g
0-3	0.70	6.1	2.1	18.0	1.7	0.33	0.277	0.028	127
"	1.31	11.5	"	"	-	0.62	-	0.031	"

Table 4.9.36. Radionuclides in sediments collected with a 145 cm² corer at Thule in August 1984. Location: B (cf. Fig. 4.2) (1409). Position: 76°40' N 70°00' W. Depth 100 m. Distance from point of impact: 24.4 km

Depth	$^{239,240}Pu$		^{137}Cs		^{241}Am	$^{239,240}Pu$ / ^{137}Cs	^{241}Am / $^{239,240}Pu$	^{238}Pu / $^{239,240}Pu$	Total
in cm	Bq kg⁻¹	Bq m⁻²	Bq kg⁻¹	Bq m⁻²	Bq m⁻²				g
0-3	0.71	13.3	4.1	76	-	0.17	-	0.020	271
"	2.3	43	"	"	8.2	0.56	0.191	0.025	"
3-6	3.5	18.3	7.3	38	-	0.48	-	0.020	76

Table 4.9.37. Radionuclides in sediments collected with a 145 cm² corer at Thule in August 1984. Location: 1407 (cf. Fig. 4.2). Position: 76°38' N 70°17' W. Depth 120 m. Distance from point of impact: 28.5 km

Depth	$^{239,240}Pu$		^{137}Cs		^{241}Am	$^{239,240}Pu$ / ^{137}Cs	^{241}Am / $^{239,240}Pu$	^{238}Pu / $^{239,240}Pu$	Total
in cm	Bq kg⁻¹	Bq m⁻²	Bq kg⁻¹	Bq m⁻²	Bq m⁻²				g
0-3	0.97 ±0.10	7.2 ±0.7	1.78	13.2	0.17 ±0.01	0.55	0.168 ±0.012	0.023 ±0.001	108

(± 1 S.E. of double determinations).

Table 4.9.38. Radionuclides in sediments collected with a 145 cm² corer at Thule in August 1984. Location: SW Kap Atholl (cf. Fig. 4.2) (1412). Position: 76°10' N 70°48' W. Depth 625 m. Distance from point of impact: 55.9 km

Depth	$^{239,240}Pu$		^{137}Cs		^{241}Am	$^{239,240}Pu$ / ^{137}Cs	^{241}Am / $^{239,240}Pu$	^{238}Pu / $^{239,240}Pu$	Total
in cm	Bq kg⁻¹	Bq m⁻²	Bq kg⁻¹	Bq m⁻²	Bq m⁻²				g
0-3	1.24	10.3	6.3	52		0.20			120
3-6	0.50	5.9	4.2	49		0.12			170
6-9	0.21	2.9	2.9	39		0.07			199
9-12	0.17	2.5	1.4	21		0.12			214
12-15	0.107	1.8	1.2	20		0.09			241
Σ		23.4		181					

Table 4.9.39. Plutonium and americium in "clean" deep sediment samples collected at Thule in August 1984

Location N	Location W	Depth m	Sediment layer cm		Bq $^{239,240}Pu$ kg⁻¹	Bq ^{241}Am kg⁻¹	^{241}Am / $^{239,240}Pu$	Station
76°30'	69°13'	245	25-30		0.0088	-		S4
"	"	"	"		0.0104 A	0.0020 A	0.197 A	"
"	"	"	"		0.0110	-		"
"	"	"	"		0.0153 A	0.0087 B	0.57 B	"
"	"	"	"	x	0.0144**	0.0054		"
				S.D.	0.0028	0.0047		
75°31'	69°17'	185	22-25		0.0146	-		V
"	"	"	"		0.0076 A	0.0064 A	0.84 A	"
"	"	"	"		0.036	0.0094	0.26	"
"	"	"	"		0.045	0.0097 A	0.22	"
"	"		"	x	0.026	0.0085*		"
				S.D.	0.0176	0.0018		

Acknowledgements

The authors wish to thank the staff of Health Physics Department for their conscientious performance of the work reported here.

Our thanks are due also to the Institute of Hygiene in Thorshavn, to the district physicians in Greenland and the telestations, GTO and all other persons and institutions in the Faroe Islands, Greenland and Denmark who have contributed by collecting samples. In particular we convey our gratitude to R.V. "Polarstern" from the Alfred Wegener Institute for Polar Research, Bremerhafen, to R.V. Bjarni Sæmundson from the Marine Research Institute in Iceland, and to Rune Dietz from the Greenland Environmental Research Institute who collected samples along northern West Greenland in 1987.

The present study was partly sponsored by the C.E.C. Radiation Protection Research Programme and by the Danish National Research Council, Danish Council for Scientific and Industrial Research and Nordic Council of Ministers (The Greenland Sea Project).

Finally we acknowledge the help of the Commission for Scientific Research in Greenland for granting permission to collect samples in Greenland.

References

1) Environmental Radioactivity in the Faroes 1962-1982. Risø Reports Nos. 64, 86, 108, 131, 155, 181, 202, 221, 246, 266, 292, 306, 324, 346, 362, 387, 404, 422, 448, 470 and 488 (1963-1983).
2) Environmental Radioactivity in Greenland 1962-1982. Risø Reports Nos. 65, 87, 109, 132, 155, 182, 203, 222, 247, 267, 293, 307, 325, 347, 363, 388, 405, 423, 448, 471 and 489 (1963-1983).
3) *A. Aarkrog, L. Bøtter-Jensen, Q.J. Chen, H. Dahlgaard, Heinz Hansen, Elis Holm, Bente Lauridsen, S.P. Nielsen, and J. Søgaard-Hansen,* Environmental Radioactivity in Denmark in 1987. Risø Report No. 563 (1989).
4) Environmental Radioactivity in the North Atlantic Region. The Faroe Islands and Greenland included. 1983-1986. Risø Reports Nos. 510, 528, 541 and 550 (1984-1988).
5) *A. Aarkrog,* Environmental Studies on Radioecological Sensitivity and Variability. Risø-R-437 (June 1979).
6) *A. Aarkrog, H. Dahlgaard, H. Hansen, E. Holm, L. Hallstadius, J. Rioseco and G. Christensen.* Radioactive Tracer Studies in the Surface Waters of the northern North Atlantic including the Greenland, Norwegian and Barents Seas. Proceedings from a Nordic Symposium on Chemical Tracers for Studying Water Masses and Physical Processes in the Sea in Reykjavik Aug 28-Sept 1, 1984. RIT FISKIDEILDAR **9.** 37-42 (1985).
9) *A. Aarkrog, S. Boelskifte, H. Dahlgaard, S. Duniec, L. Hallstadius, E. Holm and J.N. Smith.* Technetium-99 and Cesium-134 as long distance tracers in Arctic waters. Estuarine, Coastal and Shelf Science **24,** 637-647 (1987).
10) *A. Aarkrog, H. Dahlgaard, K. Nilsson and E. Holm.* Further studies of plutonium and americium at Thule, Greenland. Health Physics **46,** 29-44 (1984).
11) *A. Aarkrog, H. Dahlgaard, L. Hallstadius, H. Hansen, and E. Holm.* Radiocesium from Sellafield Effluents in Greenland Waters. Nature **304,** p. 49-51 (1983).
12) *R.S. Cambray.* Annual discharges of certain long-lived radionuclides to the sea and to the atmosphere from the Sellafield works, Cumbria 1957-1981. AERE-M 3269 (1982).
13) BNFL 1978-1985. Annual Report on Radioactive Discharge and Monitoring of the Environment. British Nuclear Fuels Limited, Risley, Warrington, Cheshire, U.K.
21) *A. Aarkrog.* Risk Assessment of long-lived radionuclides in the marine environment. Invited paper to International Symposium on the behaviour of long-lived radionuclides in the marine environment. La Specia, 28-30 Sept. 1983, p. 419- 442.
23) *H. Kautsky,* Deutschen Hydrographischen Zeitschrift **26,** 242- 246 (1973).
24) *A. Aarkrog, H. Dahlgaard, S. Duniec, P. Guegueniat, and E. Holm.* The application of seaweeds as bioindicators for radioactive pollution in the Channel and southern North Sea. To be published in the proceedings from International Symposium on radioactivity and oceanography, June 1-5, 1987, Cherbourg.
25) *A. Aarkrog (editor).* Bioindicator studies in Nordic waters. Risø-M-2517 (1985).

Bibliographic Data Sheet **Risø-R-564**

Title and authors

Environmental Radioactivity in the North Atlantic Region Including the Faroe Islands and Greenland. 1987

Edited by A. Aarkrog, E. Buch, Q.J. Chen, G.C. Christensen, H. Dahlgaard, H. Hansen, E. Holm, and S.P. Nielsen

ISBN	ISSN
87-550-1533-6	0106-2840 0900-8098

Dept. or group	Date
Health Physics Department	July 1989

Groups own reg. number(s)	Project/contract no.

Pages	Tables	Illustrations	References
84	102	35	15

Abstract (Max. 2000 characters)

Measurements of fallout radioactivity in the North Atlantic region including the Faroe Islands and Greenland are reported. Strontium-90, cesium-137 and cesium-134 were determined in samples of precipitation, sea water, vegetation, various foodstuffs (including milk in the Faroes), and drinking water. Estimates are given of the mean contents of ^{90}Sr and ^{137}Cs in human diet in the Faroes and Greenland in 1987. ^{99}Tc data on marine samples are reported. Data on plutonium and americium in sediments and biota collected at Thule in 1984 are presented.

Descriptors INIS/EDB

ACCIDENTS; AMERICIUM 241;ANIMALS; AQUATIC ORGANISMS; ATMOSPHERIC PRECIPITATIONS; CESIUM 134; CESIUM 137; CHERNOBYLSK-4 REACTOR; COASTAL WATERS; DIET; DRINKING WATER; ENVIRONMENT; FALLOUT DEPOSITS; FAEROE ISLANDS; FOOD; FOOD CHAINS; GLOBAL FALLOUT; GREENLAND; MAN; NORWAY; PLANTS; PLUTONIUM 238; PLUTONIUM 239, PLUTONIUM 240; RADIOACTIVITY; RUTHENIUM 103; RUTHENIUM 106; SEAWATER; SEDIMENTS; SOILS; STATISTICAL DATA; STRONTIUM 90; TECHNETIUM 90; TRITIUM

Available on request from Risø Library, Risø National Laboratory, (Risø Bibliotek, Forskningscenter Risø), P.O.Box 49, DK-4000 Roskilde, Denmark. Telephone 42 37 12 12, ext. 2268/2269 Telex 43 116. Telefax 46 75 56 27.

Sales distributors:
G.E.C. Gad Strøget
Vimmelskaftet 32
DK-1161 Copenhagen K, Denmark

Available on exchange from:
Risø Library,
Risø National Laboratory,
P.O. Box 49, DK-4000 Roskilde, Denmark
Phone +45 42 37 12 12 ext. 2268/2269
Telex 43 116, Telefax +45 46 75 56 27

ISBN 87-550-1533-6
ISSN 0106-2840
ISSN 0900-8098